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EVALUATION OF SO_2 EMISSION CONTROL TECHNOLOGY APPLICABLE TO THE EAST HELENA LEAD SMELTER

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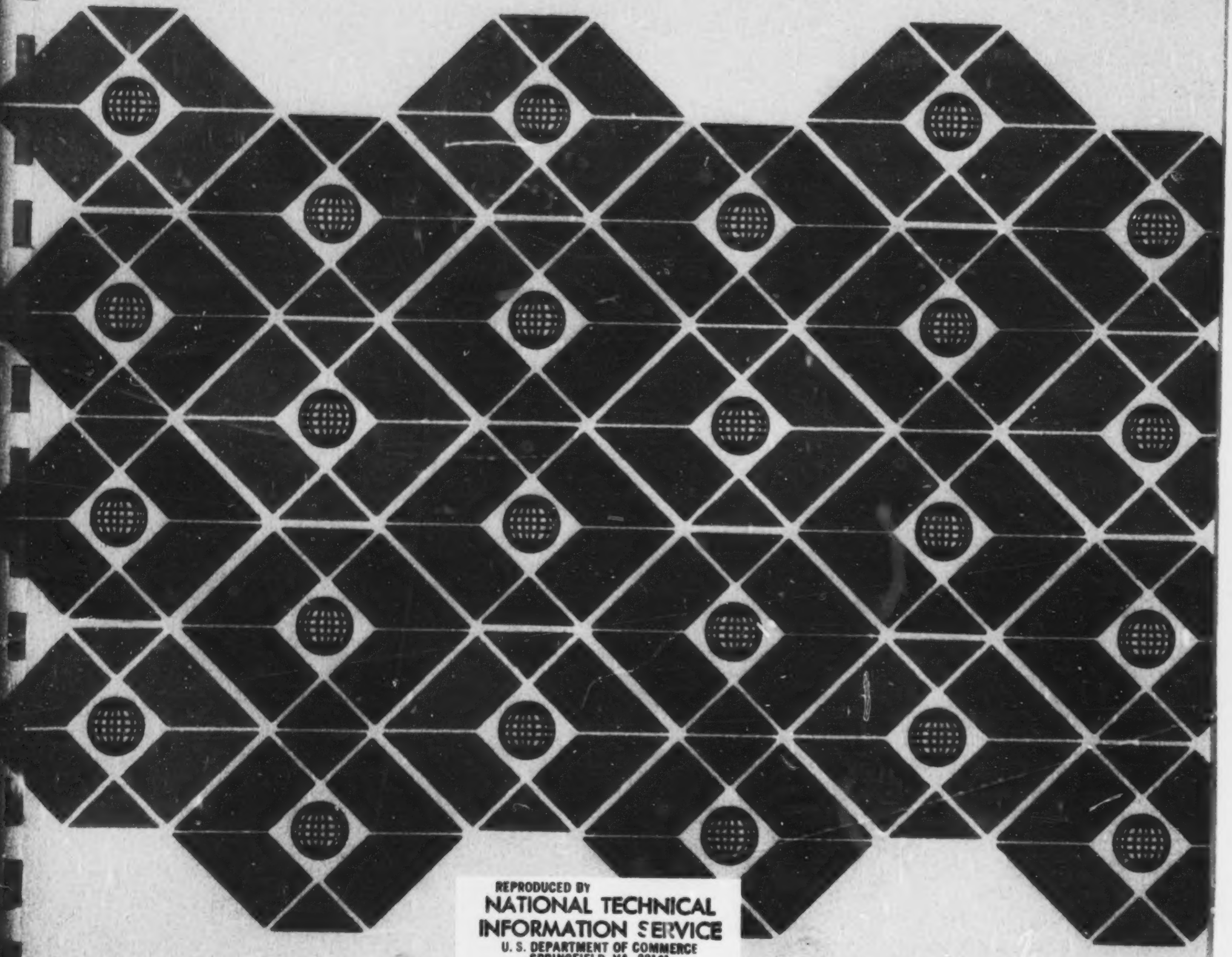

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EVALUATION OF SO_2 EMISSION CONTROL TECHNOLOGY APPLICABLE TO THE EAST HELENA LEAD SMELTER

By

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EPA CONTRACT NO. 68-02-1354 - TASK 4

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I. INTRODUCTION AND SUMMARY

There are eight operating lead smelters on the North American Continent, six in the United States and two in Canada. Of these eight operating smelters, five have installed single contact sulfuric acid plants and are using them to partially control SO_2 emissions resulting from the smelter operations and to produce a useful byproduct. Those plants with controls are able to limit SO_2 emissions with concentrations in the range of 2000 ppm to 2600 ppm from the acid plant when it is in stable operation. Up to 90% of the input sulfur to the smelter is being fixed primarily as sulfuric acid as well as in the solid material produced such as slag, bullion or stored sinter.

It is the intent of this study to determine the general practicability of applying a sulfuric acid plant to a lead smelter for SO_2 control and specifically as "reasonable available technology" for the East Helena, Montana lead smelter. This study includes analysis of the problems that have been encountered in the past, current problems, design and operating solutions to these problems, predicted SO_2 control capability, cost and practicable compliance schedules.

A brief review of the lead smelting operations normally used and the theory and design requirements for a sulfuric acid plant are presented. Visits and discussions by telephone were held with plant personnel from four smelters using sulfuric acid plants. Information was collected on operating problems and actual operating results and is summarized. An analysis of the East Helena, Montana smelter is included with design, cost and schedule considerations.

The greatest source of SO_2 emissions from this process is the lead sinter machine which, depending on the amount of sulfur in the concentrates, generates as much as 85% to 94% of the SO_2 emitted from the entire system. The sinter machine is a moving metal grate upon which the lead sulfide materials automatically react with air forming lead oxide. These machines vary from 100 to 150 feet in length and 8 to 10 feet in width. The largest quantity of SO_2 is produced in the first 40 feet of length of the machine. All of the sintering machines except one are the updraft type where the main air is forced upwards through the moving grate. Because of its mechanical complexity and hot, corrosive operating environment, normal down times are as high as 15% to 25%.

Since most of the sulfur in the concentrates processed is burned off at the upstream end of the machine, it is possible to separate this resulting rich stream from the lean downstream gas. In many cases this is done with the rich stream (4% to 8% SO_2) collected and ducted directly to the acid plant. The lean stream may either be released to atmosphere or recirculated through the sinter machine. Recirculation is possible because the oxidation reaction is completed the first 40-60 feet of grating with the remainder of the bed used for cooling. Thus, the air that is forced through the downstream bed still contains a high percentage of oxygen and can be reused either to supply oxygen for further oxidation or to provide cooling in the hot zone at the upstream end. This recirculation has the advantage of minimizing the outflow of lean gases. Current experience varies from no recirculation, with separate offgas streams, to complete recirculation with only a single stream leaving the sinter machine hood and venting to the acid plant.

There are two basic types of sulfuric acid plant designs available - the single contact plant or double contact plant. The double contact system takes advantage of the SO_2 - SO_3 kinetics by absorbing the initially generated SO_3 and partially converted SO_2 stream, resulting in a higher SO_2 to SO_3 ratio providing more efficient conversion. Acid plant manufacturers will guarantee that emissions of SO_2 from new double contact plants will not exceed 500 ppm or 2000 ppm from new single contact plants. However, a major problem in the efficient operation of acid plants fed by the offgas from lead sintering machines is the sensitivity to the concentration of SO_2 in the input gas. The single contact plant can operate with SO_2 concentration of 3.5-4% whereas, the dual contact plant requires 5-6%. Due primarily to this characteristic all acid plants serving lead smelters are the single contact systems, including those visited during this project.

While many design and operational problems have been encountered, there is no single situation that cannot be remedied by engineering design or improved operational practices. Problems such as mud like sludge material fouling heat exchangers and other system elements, excess moisture (water balance), cooling capacity available for the acid plant, intermittent operation of the sinter machine requiring frequent start-up of the acid plant, particulate and moisture removal from the gases leaving the sinter machine and extensive corrosion requiring frequent maintenance have all been encountered and solved or "worked around." The best experience indicates that the acid plant has caused less than 10% of the total smelter down time (see section IV).

The application of a single contact sulfuric acid plant to the East Helena lead smelter appears practicable to allow fixing of 70% to 80% of the sulfur entering the plant by minimum changes to the existing equipment and modifications to operating conditions. These reductions in emissions are possible in part, due to the relatively large quantity of sulfur eliminated by the sinter machine. Sulfur capture of at least 90% is technically feasible and has been accomplished by other smelters with recirculation and production of a single offgas stream from the sinter machine. However, additional development work with the specific East Helena feed material and machine would be required.

Because of considerable delays in the procurement of steel plate, the total time to install and establish an operational acid plant and its associated gas cleaning system is expected to take 40 months. This could be reduced by as much as 12 months if steel plate became readily available. Cost for the acid plant and gas cleaning system are expected to be on the order of 11-12 million dollars.

II. LEAD SMELTER OPERATIONS GENERATING SO_2 AND PARTICULATE

A. General

Lead is usually mined as a sulfide ore containing small amounts of copper, iron, zinc and other trace elements. It is normally concentrated at the mine from an ore of 3 to 8 percent lead to a concentrate of 55 to 70 percent lead. Most U.S. smelters receive between 14 and 18 percent by weight of the concentrate as sulfur. The ASARCO feed contains over 23% sulfur.

Normal practice for the production of lead from lead sulfide concentrates includes the following operations:

- Sintering in which the concentrate lead and sulfur are oxidized to produce lead oxide and sulfur dioxide. Simultaneously, the charge material made up of concentrates, recycle sinter, sand and other inert materials is agglomerated to form a dense, permeable material called sinter. This step is carried out with a sinter machine.
- Reduction of the lead oxide contained in the sinter to produce molten lead bullion. This step is carried out in a blast furnace.
- Refining of the lead bullion to eliminate impurities. This step is carried out in drossing kettles and reverberatory furnaces.

The sintering operation normally eliminates as sulfur dioxide up to 85% of the concentrate sulfur. ASARCO experience indicates that they eliminate up to 93.5% of the input sulfur based on yearly data (Reference 17). Sintering machines are operated with either a single offgas stream, two offgas streams or a single offgas stream with recirculation of the weak stream. In the case of the single stream operation, the effluent stream has an SO_2 concentration of up to 2-3 percent. In dual stream operation, the strong offgas stream has an SO_2 concentration of between 4 and 7 percent and the weak stream has an SO_2 concentration of approximately 0.5 percent. Single stream operation is accomplished by ducting all process gases under the machine hood, via a single stream, to the emission point. In dual stream operation, the stronger SO_2 laden gases at the feed end of the machine are ducted separately from the weaker gases at the discharge end of the machine. In dual stream operation with recirculation, the single offgas stream can vary from 2.5 to 6.5% (Reference 2) depending in part upon the percent recirculated.

Sinter is charged to the blast furnace periodically and typically contains up to 15 percent of the concentrate sulfur in either a sulfide or sulfate form. Emissions from the normal blast furnace due to oxidation of the remaining sulfide or thermal decomposition of the sulfates typically have concentrations of less than 1 percent SO_2 and represent approximately 7 percent of the concentrate sulfur. ASARCO eliminates approximately 1% of the smelter input sulfur at the blast furnace. The remaining sulfur is eliminated in the stack particulates, slag, matte, speiss and baghouse dust.

The refining process consists mainly of removing the impurities of copper, gold, silver and antimony from the furnace lead bullion. The furnace bullion is transferred to a series of refining kettles where drosses are selectively removed from the bullion. The drosses, containing various impurities, are treated in a reverberatory furnace for further collection of lead and concentration of other metal values. The SO_2 emissions from refining systems are essentially zero.

A breakdown of the sulfur emissions from a typical primary lead smelter operation compared to ASARCO is summarized in Table 1.

B. Sintering

The basic purpose of sintering is to convert the lead sulfide concentrate (PbS) into an oxide or sulfate form, while simultaneously producing a hard porous clinker material suitable for the rigid requirements of the blast furnace, (Reference 4.)

The sintering machine is essentially a continuous steel pallet conveyor belt moved by suitable gears and sprockets. Each pallet consists of perforated or slotted grates. Beneath the moving pallets are windboxes which are connected to suitable fans that provide large quantities of air producing a draft on the moving sinter charge. Current practice in the lead smelter industry is to blow the air through the pallets and charge (known as updraft). These updraft machines are of the Dwight and Lloyd design which may be manufactured by Lurgi or McDowell-Wellman.

Table 1. Typical Sulfur Emissions for a Primary Lead Smelter Compared To ASARCO.

	TYPICAL	ASARCO
A. Sintering machine		
Percentage of concentrate sulfur discharged in offgases	85%	93%
SO_2 concentration in single stream operation	1%	
SO_2 concentration in dual stream operation		
weak stream	0.5%	
strong stream	4-7%	
SO_2 concentration in dual stream operation with recirculation	2.5-6.5%	
SO_2 concentration with partial recirculation		2.8% 1.5% (after dilution)
B. Blast furnace		
Percentage of concentrate sulfur remaining in feed to blast furnace	15%	7%
Percentage of input sulfur discharged in gas stream	7%	1%
Percentage of input sulfur discharged in waste	8%	5%
SO_2 concentration in gas stream	0.2%	-
C. Refining operations		
Percentage of concentrate sulfur discharged	0	0

References 3 and 4.

The sinter machine has an initial ignition section which generally has a bed, approximately 1-1 1/2 inches thick, that is ignited by gas flame. The ignition layer burns for a distance of approximately 10' until it reaches maximum temperature at which point it enters the main layer. The main layer, approximately 10-14 inches thick, is laid down upon the top of the ignition layer and is ignited as the continuous moving bed travels.

The sintering reaction is autogenous and creates temperatures of approximately 1000°C. The temperature is basically controlled by the sulfur content of the sinter charge mix. Years of sintering experimentation and practice have shown that best system operation and product quality are achieved when the sulfide sulfur content of the sinter charge is between 5 and 7 percent by weight. In order to maintain the desired level of sulfur content, sulfide-free fluxes such as silica and limestone plus large amounts of recycled sinter and smelter residues (usually 50%) are added to the mix. The quality of the product sinter is usually determined by its hardness (Ritter Index) and sulfur content. There is a direct correlation between the sulfur content of the sinter and the Ritter Index, thus, high Ritter Indices usually indicate sufficiently low sulfur content in the sinter. Hard quality sinter will resist crushing during discharge from the sinter machine. Undersized sinter usually indicate insufficient desulfurizatin and is therefore, recycled for further processing. (Reference 4)

The latter half of the machine acts as a sinter cooling zone. This cooling zone serves three main purposes. First, it provides the metallurgical conditioning required for a suitable product. Second, it allows the subsequent handling of a relatively cool material; thus, conveyor belts are adequate to handle the discharged sinter. Third, potentially hazardous dust formations are minimized by cooling the product.

The concentration of sulfur dioxide versus length over the sinter machine bed is shown in the curve Figure 1. As can be seen the first third of the sinter machine length produces the maximum concentration of SO_2. If all the gases leaving the sinter machine are mixed together a concentration of approximately 1-2% SO_2 is encountered. However, if only

SO$_2$ CONCENTRATION VS. LENGTH

UP-DRAFT SINTER MACHINE

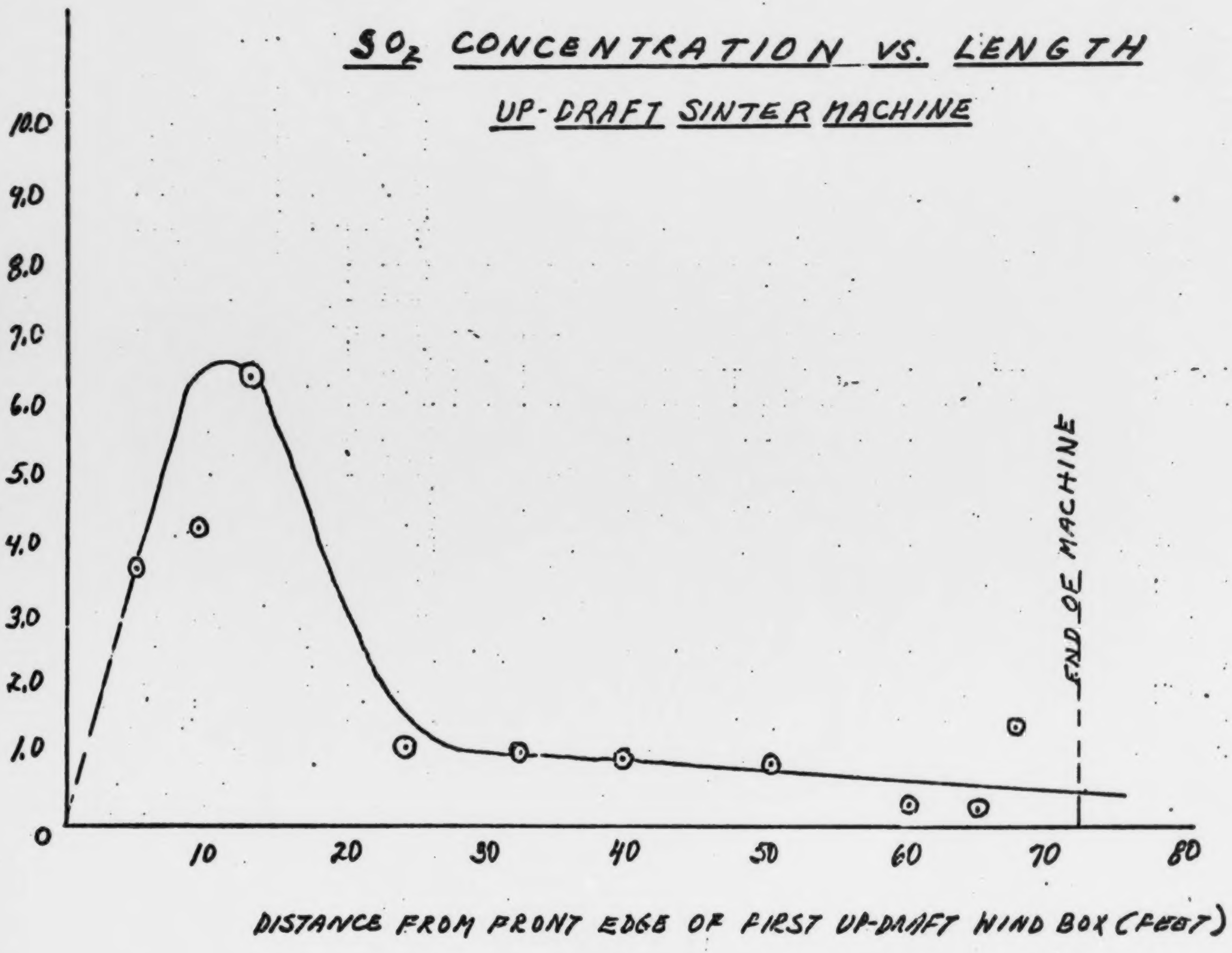

FIGURE 1

the high concentration portion of the offgases are collected separately, then it is possible to raise the SO_2 concentration to the range of 4% to as high as 8%.

With the concentration variation of SO_2 versus length in the sinter machine offgases, three different modes of operation of the system are possible. The gases can be mixed into one final offgas stream, the streams can be separated with the strong stream and weak streams going to different locations for processing or to atmosphere and finally the strong stream can be taken from the machine and the weak stream can be recirculated within the sinter machine system. Figures 2, 3 and 4 are schematics showing the three techniques.

Current practice with the three lead smelters in the U.S. using sulfuric acid plants for partial SO_2 collection incorporates a modified form of the last two techniques. The strong and weak SO_2 streams are separated, with the strong stream going to an acid plant and the weak stream going to the stack. Along with this stream separation the air flow systems are set up so that partial recirculation can be accomplished. The extent of the recirculation is adjustable and is dependent upon operating characteristics required to produce the required sinter products. In Canada 100% weak stream (30% - 40% total gas volume) recirculation is accomplished. Maximum recirculation currently encountered in the United States is 20% to 25% of the gas volume flowing to the sinter machine in SCFM.

C. Lead Reduction

Lead reduction in the domestic industry is carried out in a blast furnace. The feed material, sinter, will typically contain approximately 15% (7% for ASARCO) of the concentrate sulfur. Approximately one half of the feed sulfur to the blast furnace or 7 percent of the concentrate sulfur will be emitted to the atmosphere as a weak SO_2 stream.

The furnace is basically a water jacketed shaft furnace supported by a refractory base. Tuyeres through which combustion air is admitted under pressure are located near the bottom and evenly spaced on either side of the furnace.

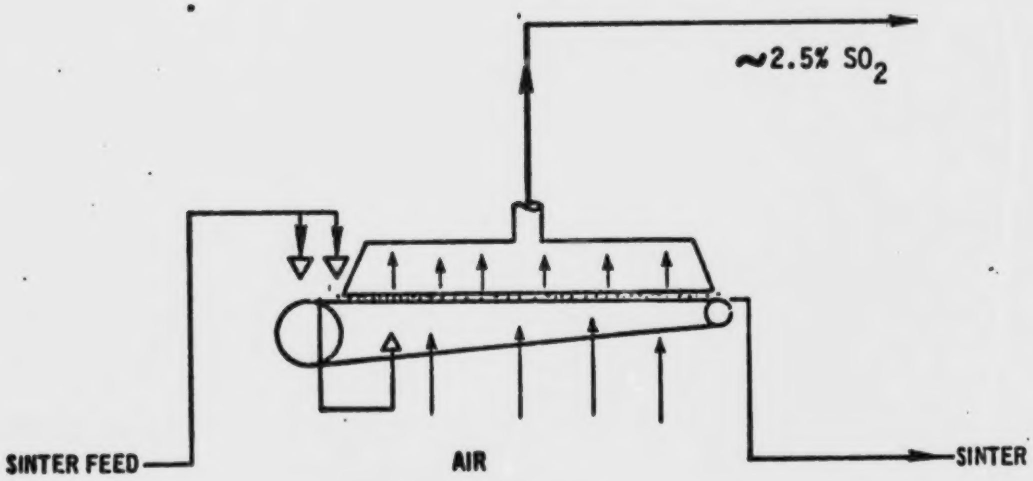
~2.5% SO₂
SINTER FEED
AIR
SINTER

Figure 2 Single stream operation.

REFERENCE 4

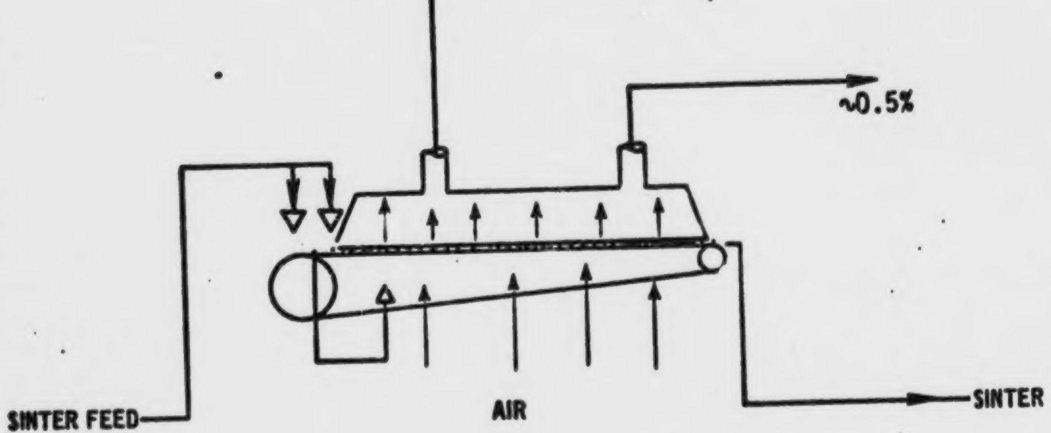
~6.5%
~0.5%
SINTER FEED
AIR
SINTER

Figure 3 Dual stream operation.

REFERENCE 4

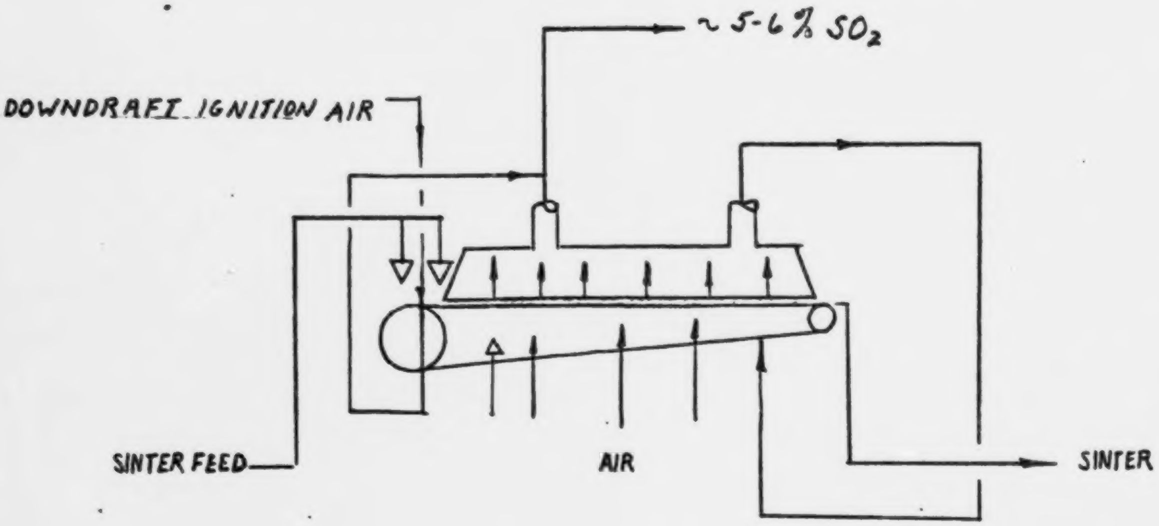
~ 5-6% SO_2
DOWNDRAFT IGNITION AIR
SINTER FEED
AIR
SINTER

FIGURE 4 DUAL STREAM OPERATION WITH RECIRCULATION

The furnace is charged with a mixture of sinter and metallurgical coke. Other materials added include limestone, silica, litharge, and slag-forming materials. Coke makes up from 8-14% of the charge, and sinter makes up from 80 to 90 percent. The remaining constituents are recycled and clean-up materials. The blast furnace takes the charge materials and reduces the sinter to lead bullion with most of the impurities being eliminated in the slag.

The principal reactions which take place in the blast furnace are:

$$PbO + CO + heat \rightarrow Pb + CO_2$$

$$C + O_2 \rightarrow CO_2 + heat$$

$$C + CO_2 + heat \rightarrow 2CO$$

The blast furnace products separate into as many as four layers, dependent upon the charge constituents and the processing circumstances. These include, from lightest to heaviest, matte (made up essentially of copper sulfide and other metal sulfides), speiss (basically arsenic and antimony), slag (largely silicates) and lead bullion. Normally, the collected slags at domestic smelters are made up of the first three layers and are collected continually from the blast furnace. The slag is either processed at the smelter for its metal content or shipped to slag treatment facilities.

Since the sintering process is not 100 percent efficient in the conversion of lead sulfide (PbS) to lead oxide (PbO), some $PbSO_4$ and small amounts of lead sulfide (PbS) remain in the product sinter. Therefore, within the blast furnace shaft there are additional lead-forming reactions involving lead sulfides and sulfates. It is these reactions which generate SO_2 during blast furnace operations. The reactions are principally:

$$2PbO + PbS \rightarrow 3Pb + SO_2$$

$$PbSO_4 + PbS \rightarrow 2\ Pb + 2SO_2$$

As a result, the effluent from a blast furnace normally contains SO_2 in concentrations ranging from a few hundred ppm to as much as 2500 ppm.

However, not all sulfur in the sinter feed to the blast furnace is eliminated as SO_2. A major portion is captured by the slag. This is dependent in part upon copper and other impurities in the sinter. Part of the sulfur in the sinter becomes fixed with the copper present, and is eliminated as slag. Thus, sulfur emissions as SO_2, from the blast furnace are in part dependent upon the amount of sulfur that becomes fixed with copper and other impurities and is captured by the slags.

Typical sulfur balances from domestic installations indicate that from 10 to 20% of the concentrate sulfur is eliminated in the blast furnace for ASARCO this value is 7%. Fully 50 percent captured by the slags. ASARCO captures 71% of the furnace sulfur in the slag. The overall sulfur eliminated from the blast furnace may seem high compared to the relatively low outlet SO_2 concentration experienced, but this is mainly due to the high volume of dilution air injected into the emission stream from the furnace. The dilution air serves two important purposes. First, it provides oxygen to allow combustion of the carbon monoxide in the discharged gas stream from the furnace shaft. If the carbon monoxide were not reacted to carbon dioxide a potentially dangerous situation would arise due to the explosive nature of carbon monoxide. Second, large volumes of air are also required to cool the exit gases from an estimated 750°C to approximately 140°C which then allows baghouse treatment for particulate removal.

III. SULFURIC ACID PLANT TECHNOLOGY

A. System

The process for the manufacture of sulfuric acid from lead smelter offgases[*] consist of three principal steps, namely:

- Purification of the sulfur dioxide (SO_2) gas from the lead sinter machine.
- Conversion of the sulfur dioxide (SO_2) gas to sulfur trioxide (SO_3) gas.
- Absorption of the sulfur trioxide (SO_3) in sulfuric acid (H_2SO_4).

B. Purification of SO_2 Gas

The sinter machine gas can normally contain combinations of metallic fume, dust, sulfur trioxide, hydrocarbons and carbon monoxide. The SO_2 gas stream entering the acid plant must be clean and dry to minimize operational problems.

The gas is usually cooled from approximately 750°F to 250°F by water sprayed in at locations varying from the sinter machine hood to a downstream spray chamber. The gases are cooled sufficiently to enter a baghouse or precipitator for major particulate removal. Then the gases pass to a spray chamber or cooling tower where water removes many of the remaining impurities and further cools the gas. Scrubber equipment has also been used for this purpose.

The gas must be cooled to reduce its moisture content. Final cooled temperature (saturation) is determined by the SO_2 concentration, product acid strength desired and the elevation of the plant above sea level. This characteristic can be seen in Figure 5 showing gas cooling required for production of 93% or 98% H_2SO_4 versus mole percent SO_2 on a dry basis. An allowance has been made in these curves to permit the addition of some water to the strong acid system to provide more flexible control of acid strength. Shell and tube type gas coolers can be used for final cooling to 100°F or less.

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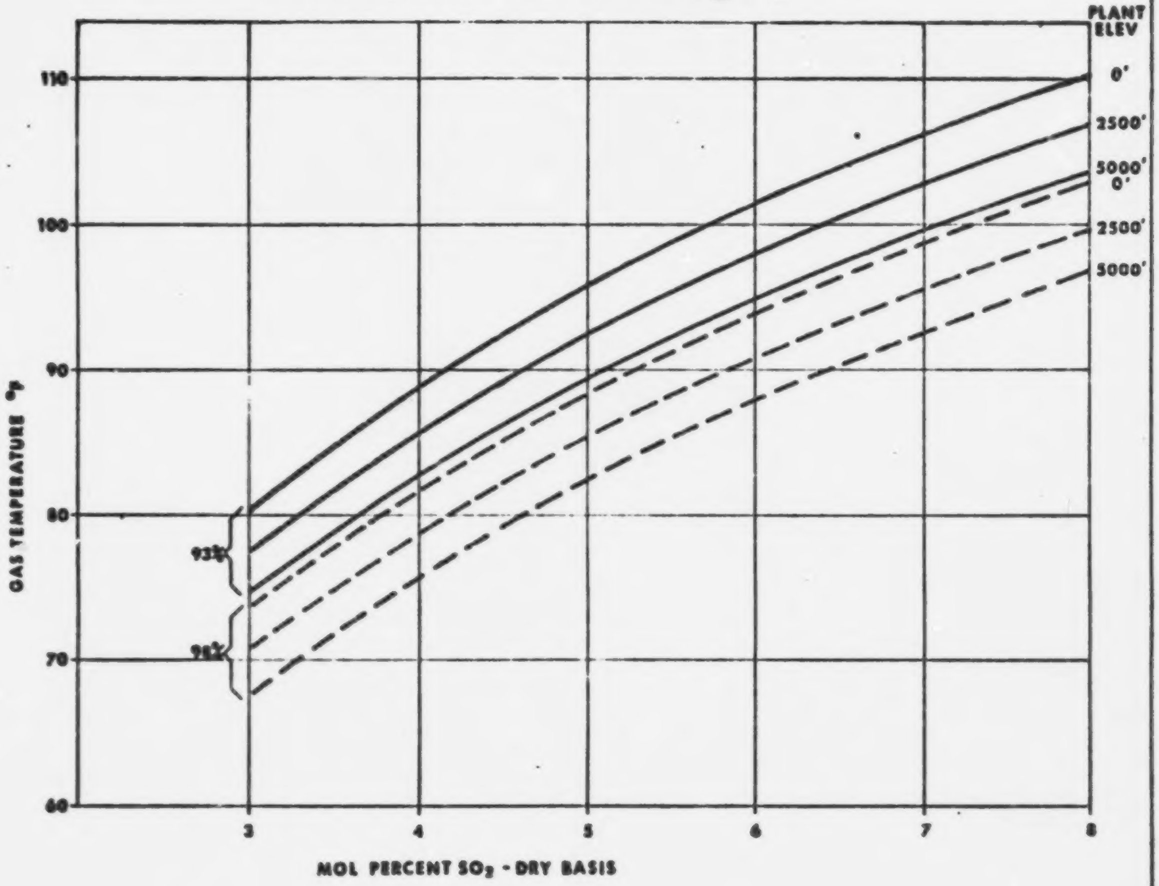
[*] See Schematic Figure 7.

GAS COOLING REQUIRED FOR PRODUCTION OF 93% OR 98% H_2SO_4



REFERENCE 5

FIGURE 5

The water discharged from the spray chamber or cooling tower will contain the impurities removed from the gas and will also be saturated with SO_2 from the gas. To recover sulfur values and reduce effluent nuisance, this water may be passed through a stripping column where a stream of air removes most of the SO_2 from the water. The SO_2 gas so recovered is fed back to the tower. The water from the stripping column then may be either neutralized or discharged.

The gas leaving the cooling section is passed through a mist precipitator in which most of the remaining particles of acid mist, metallic fume and dust are removed by electrical precipitation. Sulfuric acid mist generally contains particles less than 5 microns and is very difficult to remove from the gas stream except with an electrostatic precipitator. If this mist is allowed to enter the contact section of the acid plant it will cause corrosion problems in carbon steel ducts, heat exchangers and the main blower.

The usual mist precipitator is a tube type with vertical tubes 6-10" in diameter made of lead. High voltage discharge electrodes are suspended in the center and run the entire length of the tubes. The mist particles are attracted to the tube walls, flow downward and are collected in the lower header in the form of 5-10% H_2SO_4. Two mist precipitators installed in series can provide 99% removal efficiency. The reason for two precipitators is because the entrained acid in the gas stream tends to produce arcing and requires a reduced input voltage lowering the efficiency of the unit. With two units in series the voltage is reduced only to the first unit so the overall efficiency is affected only slightly. In most cases, only one precipitator is used to minimize capital expenditures.

The gas passes from the mist precipitator to the drying tower where it moves up through a bed counter current to the flow of 93% acid. The acid absorbs whatever moisture is present and the gas is dried to a maximum water vapor content of 5 mg/SCF. The heat generated by the absorption of water in the circulating acid is removed in heat exchangers cooled with water reducing the acid temperature to approximately 105°F.

For good SO_2 to SO_3 conversion efficiency the converter entrance gas should contain at least 1.3 volumes of oxygen for every volume of sulfur dioxide. This ratio maximizes the gas strength at the converter and determines the required volume of gas handled per ton of sulfuric acid produced. (Air is usually added to increase this ratio.)

The main gas blower usually follows the drying tower to provide sufficient suction to pull the air required through the purification system and sufficient pressure to blow the gas through the converter heat exchanger system and the absorption tower. Blower static pressure capability is typically 150" W.C.

The gas leaves the blower at about 130°F and flows through a series of heat exchangers in which its temperature is raised to 820°F which is the required temperature for entering the first catalyst layer in the converter.

The dry gas leaving the blower passes through the shell side of three (usually) shell and tube heat exchangers in series in which its temperature is raised to 820°F. In the cold heat exchanger, the SO_2 gas is heated to approximately 480°F as it flows counter-current to the SO_3 gas leaving the converter. In the intermediate exchanger, the SO_2 gas is further heated to about 555°F by cooling the gas leaving the second bed of the converter. Further heating of the SO_2 gas to 820°F is accomplished in the hot, or converter, heat exchanger by cooling the partially converted gas leaving the first catalyst bed from about 1075°F to 820°F. Suitable by-passers are provided around these exchangers to permit maintaining optimum temperatures to the converter. An SO_3 cooler utilizing forced air may also be provided to further cool the SO_3 gases leaving the cold heat exchanger before they enter the absorption tower. Operation of the plant can be maintained with any of the three heat exchangers blanked and taken out of service by the use of the SO_3 cooler for heating the SO_2 gas and the introduction of quench sulfur dioxide gas at strategic points for temperature adjustment.

C. Conversion of SO_2 to SO_3 and Absorption.

The conversion of SO_2 to SO_3 takes place in the converter. The converter contains several layers of a vanadium pentoxide catalyst, the purpose of which is to accelerate the reaction between SO_2 and oxygen to form SO_3. The converter is normally of the three stage four bed type, designed to provide maximum conversion efficiency.

The heat of reaction generated in the first stage of conversion where 70-75% of the SO_2 reacts with O_2 in the gas stream is removed from the gas in the external converter heat exchanger. The temperature rise may be 250-300°F. The rise in temperature reduces the conversion equilibrium. See Figure 6 . The partially converted gas, cooled to 820°F in the converter heat exchanger, is returned to the second stage. The heat of reaction in the second mass is also removed in an external intermediate exchanger. Heat from the third and fourth beds is removed in the external cold heat exchanger and SO_3 gas cooler. As indicated above, the SO_3 gas leaving the converter is cooled in the tube side of the cold heat exchanger and SO_3 cooler by preheating the SO_2 gas leaving the blower and by forced air respectively.

An indirect air cooler reduces the SO_3 temperature to 300-350°F before going to the 98% absorption tower where its SO_3 content is absorbed in the 98% sulfuric acid recirculating over the tower. The heat rise in the acid resulting from (a) the transfer of 93% acid, (b) heat of absorption of SO_3, and (c) from the sensible heat in the incoming gas, is removed from the acid as it flows by gravity through the 98% acid cooling heat exchangers to the pump tank. The exchangers are designed to reduce the acid temperature to 150°F. A vertical submerged pump recirculates the 98% acid over the absorption tower and also delivers the product 98-99% acid to the acid storage coolers or to the 93% acid system for dilution.

For heating up the converter system, valved ductwork is provided from the blower discharge to a heat source, either a separate gas fired heater or from some other source in the plant.

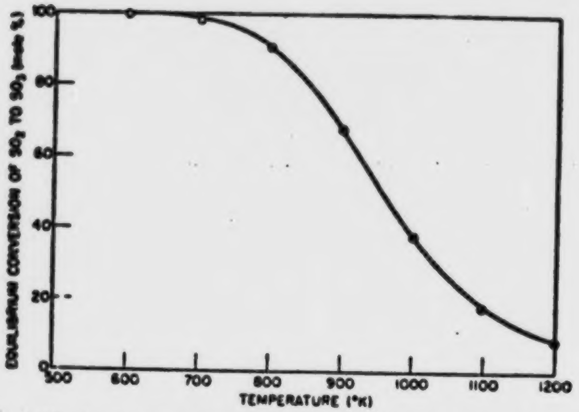


Figure 6 Effect of temperature on the equilibrium conversion of sulfur dioxide to sulfur trioxide. (Initial sulfur dioxide concentration 8.0 per cent by volume.)

REFERENCE 1

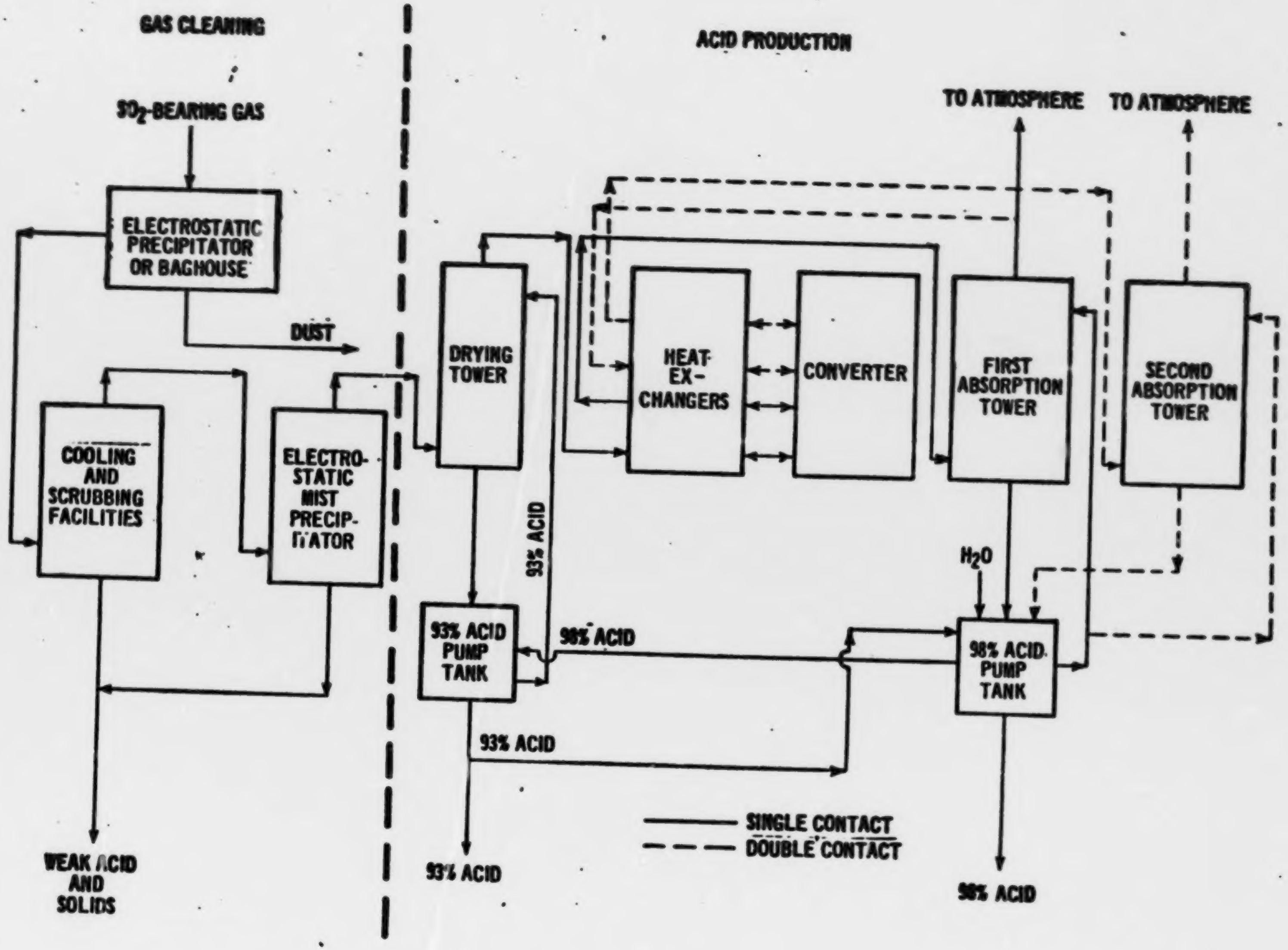
FIGURE 6

The double contact acid plant is the same as a single contact with the exception that the partially stripped gases at a higher SO_2 to SO_3 ratio are again passed through a portion of the converter and a second absorption tower. With this approach a 500 ppm acid plant (new) emission can be guaranteed compared to 2000 ppm for a single contact. Figure 7 shows a single and double contact sulfuric acid plant schematic.

A clear discussion on the relative merits between single and double contact systems for metallurgical plants is presented below from Reference 16.

"High sulfur dioxide concentrations are advantageous because they produce more acid for a given size plant. However, oxygen concentrations decrease as sulfur dioxide concentrations increase, and the oxygen concentration has a significant effect on catalyst performance and yield. For this reason, optimum sulfur dioxide concentration in a conventional metallurgical type contact plant is approximately 7.0 to 7.5% by volume. In the double contact or "interpass absorption" type plants first developed by Bayer in Germany, the optimum concentration is approximately 9.0% SO_2. However, equipment must be added to handle this stronger gas.

As sulfur dioxide concentration decreases, small fractions of the reaction heat are available to preheat incoming cold gases. At approximately 3.5 to 4.0% SO_2 the single contact acid plant is thermally balanced and any lower concentrations require the addition of external heat. The preheater provided for plant start-up can be used for this purpose but its continuous operation adds extra maintenance and fuel costs to the cost of acid production. It should also be noted that heat exchanger sizes increase rapidly as sulfur dioxide concentration decreases. With the double contact process, thermal balance occurs at approximately 6.0 to 7.0% SO_2 with 7.5% preferred as a practical lower limit."


GAS CLEANING
ACID PRODUCTION
SO2-BEARING GAS
ELECTROSTATIC PRECIPITATOR OR BAGHOUSE
DUST
COOLING AND SCRUBBING FACILITIES
ELECTROSTATIC MIST PRECIPITATOR
WEAK ACID AND SOLIDS
DRYING TOWER
93% ACID
93% ACID PUMP TANK
98% ACID
93% ACID
93% ACID
HEAT-EX-CHANGERS
CONVERTER
TO ATMOSPHERE
TO ATMOSPHERE
FIRST ABSORPTION TOWER
SECOND ABSORPTION TOWER
H2O
98% ACID PUMP TANK
98% ACID
SINGLE CONTACT
DOUBLE CONTACT

SINGLE AND DOUBLE CONTACT SULFURIC ACID PLANT SCHEMATIC

FIGURE 1

IV. LEAD SMELTERS WITH SULFURIC ACID PLANT SO_2 CONTROL

A. Introduction and Summary

There are six lead smelters currently operating in the United States and two in Canada. Of these eight smelters, five are using sulfuric acid plants to obtain partial or nearly complete SO_2 control from the major source, the sinter machine. This evidence conclusively proves that the technique is now "reasonably available technology."

Many specific problems have been encountered and have been solved with varying degrees of success at each smelter. Available knowledge and experience throughout the industry, however, is sufficient to permit engineering design and operational techniques to obviate major problems that have arisen in the past.

Three lead smelters using sulfuric acid plants were visited and data from a fourth obtained by telephone and from the EPA. Operating problems were discussed with plant personnel. Similar problems were encountered by most of the smelters. In no case, was a problem encountered that could not be resolved by engineering design or worked around by suitable operating procedures. Many of the problems that still exist are the result of lack of recognition during the initial design phase or poor equipment selection. Additionally, economic considerations tend to minimize capital expenditures requiring operating personnel to "make do" with the equipment available as long as possible with consequent more frequent breakdowns with age or operation at below design capability.

During normal operation single contact sulfuric acid plants have been measured at maximum tail gas concentrations of 2,000 PPM. This value is guaranteed by the plant designers for new plants.

Significant factors relating to each smelter are included in this section. Complete notes from each of the discussions with smelter personnel and acid plant vendors are included in the Appendix to this report.

The average lead, sulfur and zinc contained in the input concentrate for each of the smelters is shown in Table 2. The lead to sulfur ratio varies significantly from 1.0 to 4.2. This factor will have a significant effect on the operation of the sinter machine system and should be considered when comparing results.

Plant input sulfur recovery, or fixing, with a single contact sulfuric acid plant directly receiving sinter machine offgas can normally be at least 66% as manufactured sulfuric acid and an additional 4% leaving slag, bullion or stored sinter. Each of these plants only use the rich SO_2 stream from the sinter machine for the acid plant, with lean stream to atmosphere. Lower percent sulfur fixed as acid can also occur depending on the plant operating conditions.

In one case where the smelter is operating with complete recirculation of the sinter machine lean gas and only a single stream is removed, 86% of the plant input sulfur is fixed as manufactured sulfuric acid. With the additional 4% sulfur fixed in the slag, bullion or stored sinter, overall plant input sulfur fixing reaches 90%. This again is based on yearly production figures.

B. St. Joseph Lead, Herculaneum, Missouri

The St. Joseph Minerals Corporation Lead Smelter at Herculaneum, Missouri has a conventional updraft sintering machine with a 300 ton per day acid plant to collect strong stream, only, SO_2 rich gases. The usual material mixing systems and blast furnace with refinery kettle systems are also used. The plant schematic is shown in Figure 8. All of the gas streams from the plant are combined to flow through a single baghouse capable of handling 550,000 ACFM.

Concentrate analysis is shown in Table 2. The following Table 3 shows material process capability.

TABLE 2

AVERAGE CONCENTRATE INPUT TO SMELTER

	Pb %	Zn %	S %	Pb/S
Brunswick	35	9	30	1.2
Bunker Hill	65	6	18	3.6
St. Joe	72		17	4.2
Amax	70		15	4.7
ASARCO. E. Helena	22	8.5	23	1.0

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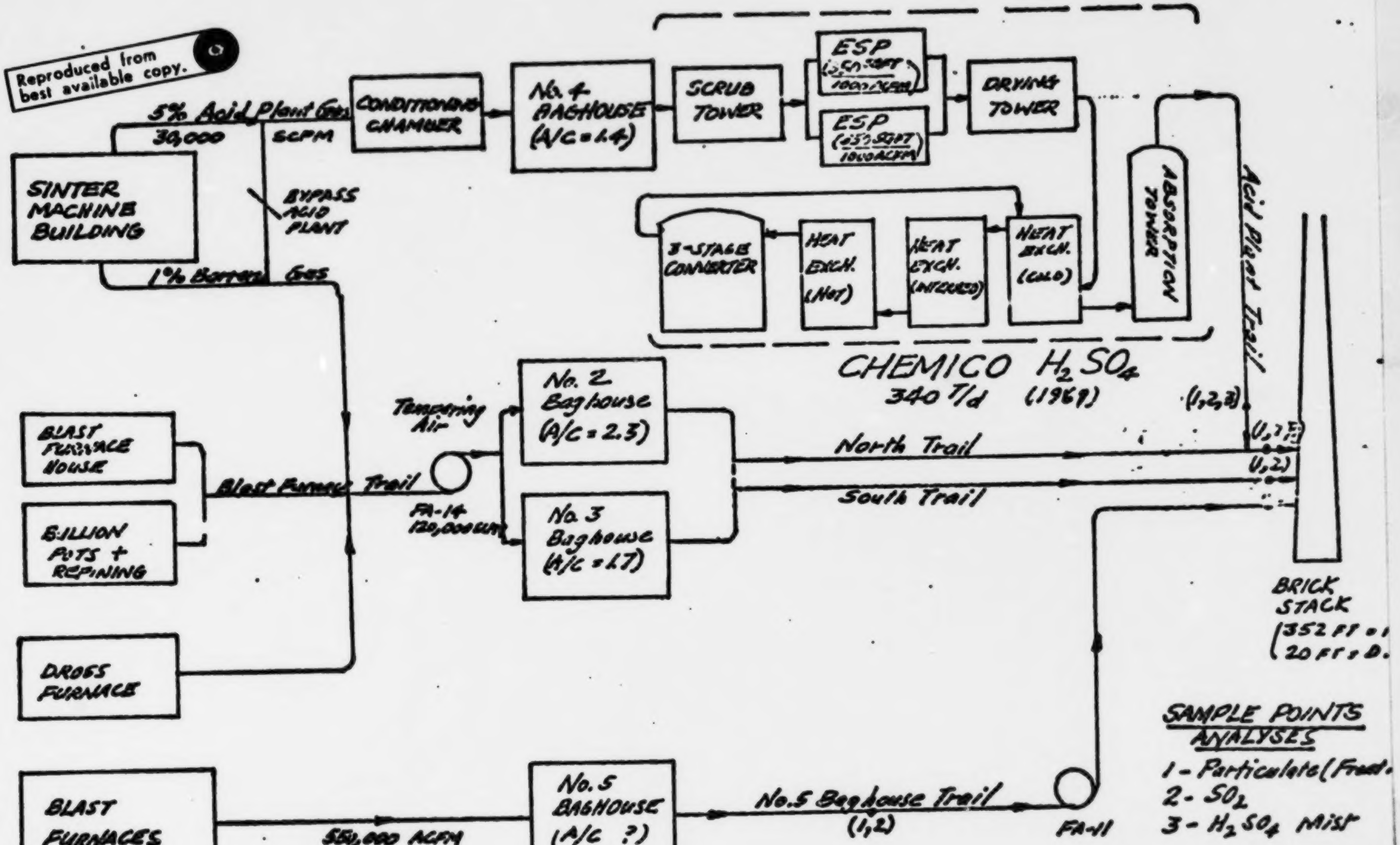

SINTER MACHINE BUILDING
5% Acid Plant Gas
30,000
SCFM
BYPASS ACID PLANT
1% Borrow Gas
CONDITIONING CHAMBER
No. 4 BAGHOUSE (A/C = 1.4)
SCRUB TOWER
ESP
ESP
1000 ACFM
DRYING TOWER
ABSORPTION TOWER
3-STAGE CONVERTER
HEAT EXCH. (HOT)
HEAT EXCH. (INTERMED)
HEAT EXCH. (COLD)
CHEMICO H2SO4
340 T/d (1969)
Acid Plant Trail
(1,2,3)
(1,2)
BLAST FURNACE HOUSE
BULLION POTS + REFINING
DROSS FURNACE
Blast Furnace Trail
Tempering Air
FA-14
120,000 CFM
No. 2 Baghouse (A/C = 2.3)
No. 3 Baghouse (A/C = 1.7)
North Trail
South Trail
BRICK STACK
(352 FT
20 FT
BLAST FURNACES
550,000 ACFM
No. 5 BAGHOUSE (A/C ?)
No. 5 Baghouse Trail
(1,2)
FA-11
SAMPLE POINTS
ANALYSES
1 - Particulate (Fred.
2 - SO2
3 - H2SO4 Mist

ST. JOE MINERALS (1890)
Herculaneum, Mo.
225,000 Ton Lead/yr

FIGURE 8

D.H.PRAH
9-19-73

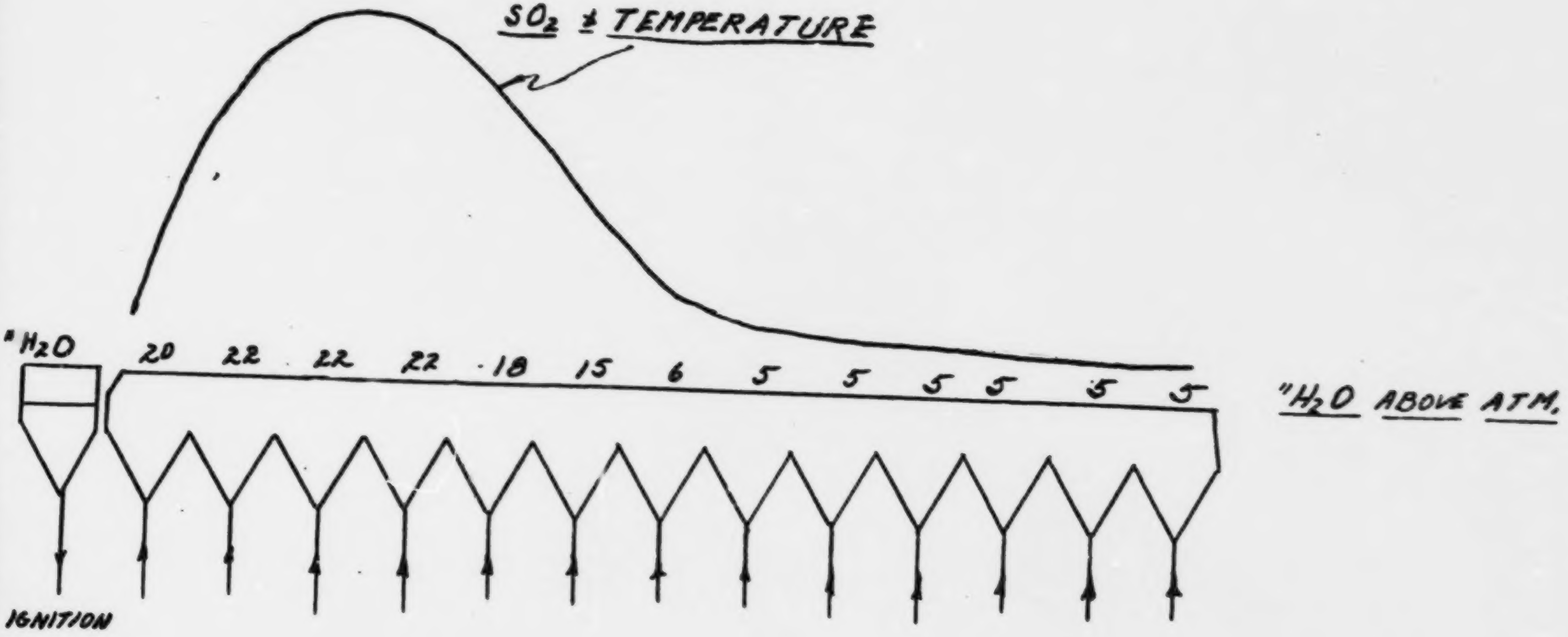
TABLE 3

ST. JOSEPH MATERIAL HANDLING CAPABILITY

Units	Design TPD	Normal TPD	Max TPD
Sinter	3,336	3,504	4,392
Furnace	1,536	1,632	2,040
Dross Reverb	144	168	216

The 10 feet wide by 105 feet long sinter machine offgas flow rate is approximately 40,000 SCFM. The sinter machine has thirteen windboxes. Figure 9 is a sketch showing the SO_2, temperature and pressure distribution at various points along the length of the sinter machine. The distribution curves are typical of this type of machine with maximum sulfur and temperature at the upstream end. A downdraft system is used for ignition. After adding slag consisting of iron oxide, carbon dioxide and calcium oxide to the concentrate, the sulfur content is reduced by approximately 1%. 52% recycle material is added resulting in a 46% lead and a 12% sulfur feed to the sinter machine. Recycle sinter material consists of 46% lead and 1% sulfur. Final sulfur content consisting of 12% of the original concentrate plus 1% from the recycle is 6.5%. This percentage is required to maintain proper bed temperature during burning of the material.

A large amount of water is sprayed in at the sinter machine hood very close to the off take to the acid plant. Input water is approximately 120 lbs/min. It is estimated that there is approximately 4% moisture in the charge which adds an additional 207 lbs/min. A total of 12% water is included in the gases from the sinter plant. The injected water is required to cool the gases to approximately 150°F before entering a baghouse for particulate collection. Acrylic bags are used. This baghouse is insulated to minimize corrosion.


SO_2 & TEMPERATURE
"H_2O
20
22
22
22
18
15
6
5
5
5
5
5
5
"H_2O ABOVE ATM.
IGNITION

ST. JOE SINTER MACHINE SO_2, TEMPERATURE AND PRESSURE DISTRIBUTION

FIGURE 9

The single absorption acid plant produces 93% acid. An SO_2 gas stream temperature reduction to 93 - 96°F is required to eliminate sufficient moisture for this plant to operate satisfactorily. This requires 1500 GPM of cooling water for the heat exchangers.

3.5 - 3.6% SO_2 is required in the gas for autogenous operation. There is not sufficient heat available in the acid plant to use in any other part of the plant. It is estimated that approximately 55% of the input sulfur goes to the sulfuric acid plant. Approximately 53% of the input sulfur is converted to sulfuric acid.

Problems encountered at this plant appeared to be greater than at any of the other lead smelters using sulfuric acid SO_2 control. The major problem appears to be excessive moisture (water) present within the sinter machine offgas and acid systems. This excessive water causes a water balance problem with difficulty in maintaining acid product concentration as well as introducing corrosion as a result of condensation in various parts in the system.

The flotation reagent problem (see Section V), also seems to be present to a greater extent in this plant. They have measured approximately 1.2 lbs. of flotation reagent oil in one ton of concentrate. The "mud" deposits form in many places especially in the heat exchanger systems requiring frequent (almost daily) cleanout of these heat exchangers. Since the heat exchangers are not designed for easy disassembly, excessive downtime is encountered.

Excessive corrosion has resulted in heat exchanger being completely retubed after five years of operation. Condensation within the baghouse results in excessive corrosion even though insulated. Corrosion is en- countered in the screw conveyor and the shaker mechanism. In addition, only one year bag life has been obtainable. Condensation in the baghouse at times has included some free sulfur particularly with a deficiency of oxygen at the sinter bed.

The start of the sinter machine takes approximately one half hour before the off gases are sufficiently stabilized to allow passing them to the acid plant.

The water supply to the heat exchangers contains some impurities which further cause plugging on the cooling side of these units.

C. Amax Lead, Boss, Missouri

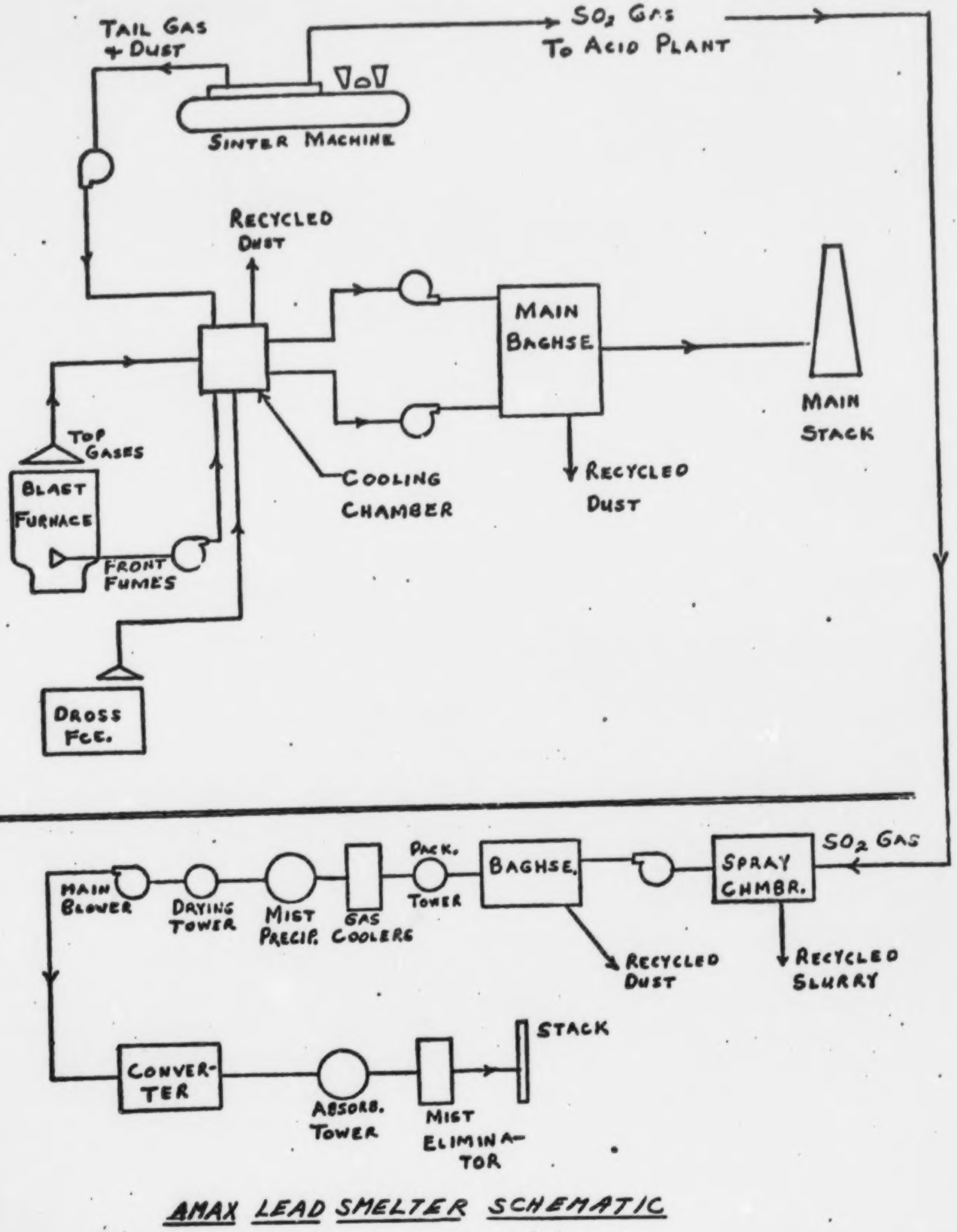
The Amax Lead Smelter at Boss, Missouri is a conventional lead smelter using a Lurgi sinter machine. The sinter machine uses 40,000 SCFM gases (air) of which 22,000 SCFM is passed through the acid plant. The gas stream to the acid plant contains an average of 5.5% SO_2 varying from 4.9% to 7%. Input concentrate contains 70% lead and 15.0% to 15.5% sulfur. Half of the sinter machine feed is recycle sinter. Total sinter machine feed is approximately 670,000 TPY.

Some recirculation of the gas from the downstream end of the sinter machine is accomplished. The gases from the upstream end of the machine are at 600°F and go to the spray chamber. Gases from the downstream end of the machine leave the hood at 350°F. The gases going to the acid plant are reduced in temperature at the spray chamber from 600°F to 250°F. Approximately 25 GPM (200 lbs/min) of water is used in the spray chamber.

The original acid plant installed in 1968 was designed for 200 TPD and they are presently running at 240 to 250 TPD. Original cost was $2,500,000. The plant has a 4 pass converter.

After the spray chamber the gases have been passed through a baghouse. This has resulted in considerable problems in bag maintenance. They are presently building a precipitator to replace the baghouse. A Venturi scrubber will be used downstream of the precipitator. A schematic of the plant is shown in Figure 10.

Operating experience with the sinter machine is the same as in other plants with frequent shutdowns for maintenance. Two days per week, Tuesdays and Thursdays are used for standard maintenance downtime. It is estimated that at no other time is the sinter machine down for more than


TAIL GAS
+ DUST
SO2 GAS
TO ACID PLANT
SINTER MACHINE
RECYCLED
DUST
MAIN
BAGHSE
MAIN
STACK
TOP
GASES
BLAST
FURNACE
FRONT
FUMES
COOLING
CHAMBER
RECYCLED
DUST
DROSS
FCE.
SO2 GAS
MAIN
BLOWER
DRYING
TOWER
MIST
PRECIP.
GAS
COOLERS
PACK.
TOWER
BAGHSE.
SPRAY
CHMBR.
RECYCLED
DUST
RECYCLED
SLURRY
CONVER-
TER
ABSORB.
TOWER
MIST
ELIMINA-
TOR
STACK

AMAX LEAD SMELTER SCHEMATIC

FIGURE 10

8 hours per day. The sinter machine on time is approximately 75%. However, start and shut down of the acid plant does not appear to be a serious problem.

One sixth of the acid plant operating cost is expended in the annual 3-4 week shutdown for maintenance. This maintenance includes the following:

- Screening the catalyst bed
- Cleaning the cooling coils and heat exchangers
- Clean out gas ducts of dust
- Mist precipitator maintenance
- Packed tower cleanout (every two years)
- Spray chamber repair and leak elimination

A mist eliminator was required downstream of the mist precipitator. It completely solved the mist emission problem.

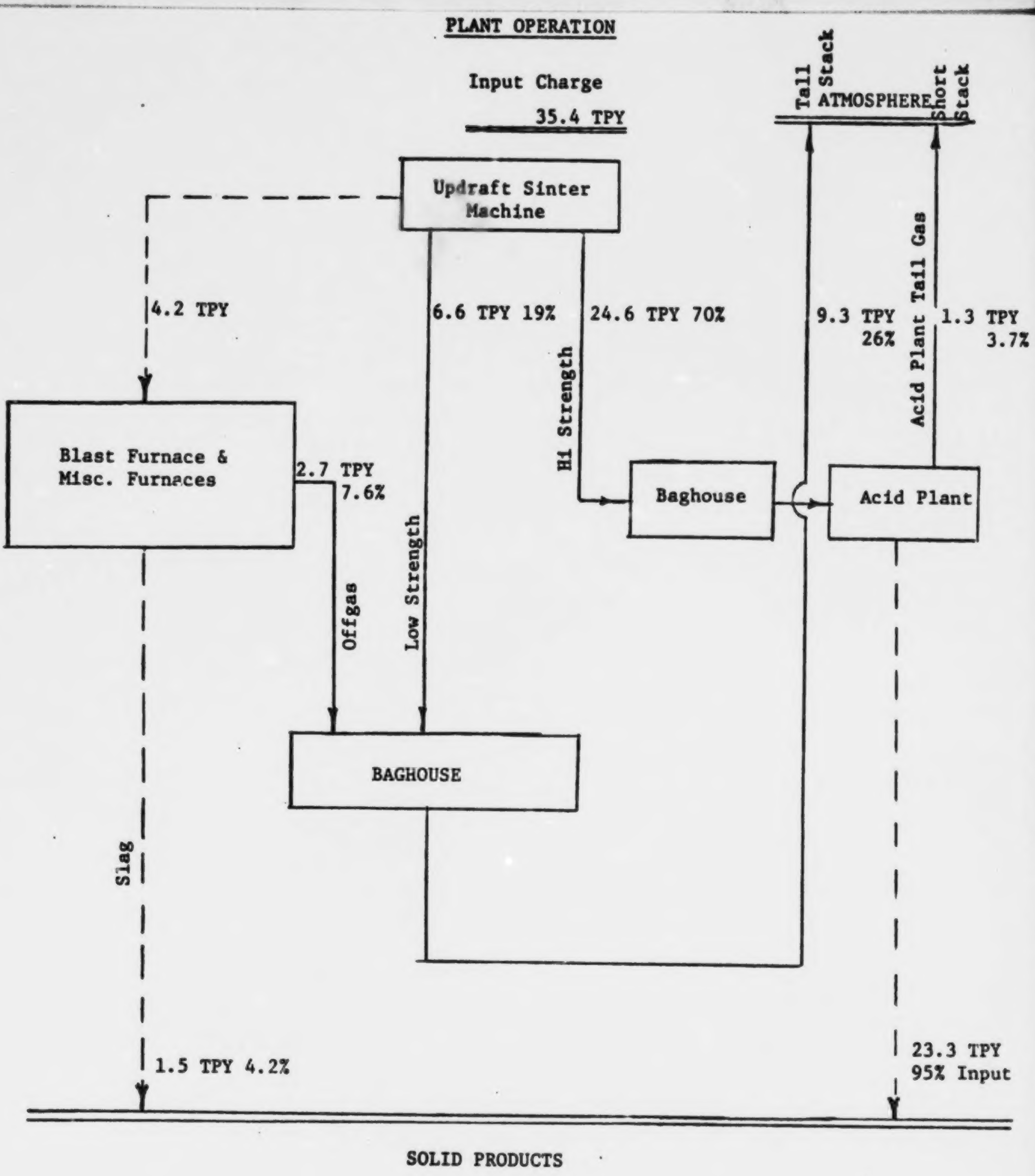
D. Bunker Hill, Kellogg, Idaho

The Bunker Hill Smelter uses a conventional Lurgi updraft sinter machine 8 feet wide and 96 feet long. Capacity of the sinter machine is approximately 2700 wet tons per day. Operating on time experience is 75%-85%. The sinter machine was installed in 1970. Part of the off-gases are passed to a sulfuric acid plant and the remainder to the stack.

Burn through on the sinter machine occurs at approximately 40 feet and complete sulfur burnout at 60 feet. From 60 feet to 96 feet cooling occurs.

The acid plant is a 300 ton per day single absorption plant. The 700°F gases pass from the sinter machine hood, where no water is injected, into a water spray chamber where they are cooled to approximately 230°F. The gases then enter a baghouse for particulate removal. After the baghouse they enter a packed tower which is used as a cooling device as well as an additional particulate collector. From the cooling tower the gas is passed into a mist precipitator and then into the acid plant drying tower. The smelter system is shown in Figure 11.

732,000 TPY of concentrate are used in the lead smelter. The concentrate contains 65% lead, 6% zinc and 18% sulfur. The concentrate comes


PLANT OPERATION
Input Charge
35.4 TPY
Tall Stack
ATMOSPHERE
Short Stack
Updraft Sinter Machine
4.2 TPY
6.6 TPY 19%
24.6 TPY 70%
Hi Strength
9.3 TPY 26%
Acid Plant Tail Gas
1.3 TPY 3.7%
Blast Furnace & Misc. Furnaces
2.7 TPY 7.6%
Baghouse
Acid Plant
Offgas
Low Strength
BAGHOUSE
Slag
1.5 TPY 4.2%
23.3 TPY 95% Input
SOLID PRODUCTS

BUNKER HILL

SULFUR BALANCE - LEAD SMELTER

FIGURE 11

from various locations. At least 30 different types of concentrate are encountered during one year. The acid plant handles approximately 32,000 SCFM.

Startup and shutdown of the sinter machine and acid plant has been handled with reasonable success.

The 75%-85% on time for the sinter machine appears to be normal experience in the industry. On startup of the sinter machine it takes from 5-20 minutes to be able to obtain autogenous operation of the acid plant. During this low startup flow condition chanelling of the gases through much of the equipment such as the towers and the precipitators occurs. This chanelling reduces the efficiency of the equipment, to a point where it may be as low as 82%. It takes from 20-40 hours to get the third pass out of the converter up to a maximum heat.

They do encounter the black "mud" deposit and believe it is the hydrocarbon flotation reagent material in the concentrate. This material builds up in various places in the system and must be cleaned out periodically. They do get a build up of mud at the bottom of inlet side of the tubes in the precipitator and it is necessary to keep these clean to obtain efficient precipitator operation.

They use a preheater for start up of the converter but it has given them problems because of the moisture in the ambient air introduced and resultant corrosion in the system.

They have encountered excessive corrosion in the inlet duct of the blower and in the blower itself. They believe that there is still some acid mist coming in at this point.

Mist corrosion is also encountered in the outlet duct from the baghouse to the fan and in the fan housing.

They change bags in the baghouse at least once a year.

They are able to detect when plugging occurs in the heat exchangers by increase in the drip acid at a drain pipe which is located at the inlet to the blower. This drain pipe is checked every 24 hours.

E. Brunswick Smelting and Refining, Belladune, New Brunswick, Canada

This lead smelter was built in 1967. It has a 10 ft. wide by 150 ft. long Lurgi sinter machine operating with complete recirculation. This results in a single off-gas stream leaving the machine of 50,000 SCFM at a temperature of 550°F to 575°F with 4% to 6% SO_2. Gases go directly to a single contact acid plant by way of a hot gas precipitator, three Venturi scrubbers in parallel and twelve mist precipitators in parallel.

No water is injected into the gases until they reach the Venturi scrubbers. These scrubbers have a very low pressure drop and are used primarily for cooling and some mist elimination.

The high sulfur content of the concentrate (30%) requires a 5:1 sinter recycle to machine feed mix. Complete air supply to the sinter machine is produced by three fans with one additional fan for ignition air. Ignition of the ignition layer is accomplished by No. 6 fuel oil burners.

No evidence of "mud" deposits is encountered. They do find a sludgy grayish yellow, non oily material that is readily washed out with water.

Sea water is used for cooling. An acid plant water balance problem is encountered in the summer only. Additional heat exchange surface is being added to resolve this problem.

With the recirculation sinter machine system, 86% of the smelter input sulfur is captured as sulfuric acid. Additional sulfur capture in the solid materials leaving the plant such as slag and lead raises the total to 90%.

They do not have any major problems with frequent starts on the acid plant. A preheater and insulation are used to maintain temperatures for start. Constant maintenance is required on the mist precipitators. Each unit is taken off the line every 7 to 10 days for cleaning. Sinter machine availability averages 80%. Downtime due to acid plant problems is less than 10% of the total downtime for the entire smelter. Two parallel cooling towers in the plant allow alternation for cleaning purposes.

V. SULFURIC ACID PLANT OPERATION WITH A LEAD SINTER MACHINE - PROBLEMS AND SOLUTIONS

Many difficulties have been encountered with the operation of sulfuric acid plants using offgases from a lead sinter machine. However, currently, production of sinter and acid has been sustained over long operating periods. This experience has been obtained at St. Joseph Lead, Herculaneum, Mo., AMAX, Voss County, Mo., and Bunker Hill, Kellogg, Idaho in the United States and Cominco and New Brunswick Smelters in Canada.

In general, it can be said that since the first acid plant was used in conjunction with a lead smelter, considerable experience has been obtained and all of the problems can be solved by good engineering design and operational procedures. These problems will be discussed.

Normal operation of a lead sinter machine encounters considerable maintenance problems. This results in scheduled and unscheduled down times for the sinter machine of approximately 15% to 25%. These problems seem to be inherent in the operation of a moving mechanical device in conjunction with the high temperature lead sinter material and the general complexity of the machine. In addition, the control of the metallurgical properties of the sinter must predominate and is dependent upon sinter composition, available oxygen at various points along the bed and sulfur content. The complexity of the air supply system, with from 4 to 8 fans supplying air each with damper or speed controls, further complicates the adjustment of the machine. There does not, at this time, appear to be a solution to reducing the down time of existing design sinter machines to less than 15%.

Therefore, it becomes necessary to accept the fact that the SO_2 stream will be interrupted to the acid plant as long as there is no auxiliary source. (Cominco uses an intermediate concentration process before sending offgas to the acid plant.) The acid plant is normally a steady state system because of internal process characteristics.

In starting an acid plant, it is necessary to build up the flow to converter to allow autogenous operation. It usually takes from twenty minutes to half an hour to start up an acid plant once the sinter machine has established equilibrium operation and sufficient SO_2 stream concentration. Frequent starts and shutdowns of the acid plant can result in cooling down all the acid system and thereby causing corrosion due to passage through the dew point and slow start-up of the converter. The addition of insulation and preheaters supplying auxiliary heat can minimize or eliminate both the start-up time and corrosion in the associated acid plant. Start-up and shutdown with present plant experience does not appear to be a major problem and can be controlled. This is being done at Amax, Bunker Hill and Brunswick with direct connected acid plants.

One of the most difficult problems presently encountered appears to be that of formation of a "mud" that travels through the entire system all the way through to the final product acid. It is believed that the black material comes from a flotation reagent oil that remains in the concentrate as delivered to the plant. It should be noted that this theory is somewhat speculative, but is generally agreed to by both the acid plant vendors and the smelter operators. In some cases it has been found that 1.2 lbs of oil per ton of concentrate has been present.

The main output of this oil or hydrocarbon in the offgases comes from the down draft ignition area. Here the temperature is low and the hydrocarbons do not get a chance to burn completely to CO_2. In some cases, a large quantity of water is sprayed in almost immediately above the hot zone of the sinter machine just downstream of the ignition zone, further reducing the chance of reacting any unburned hydrocarbons that may be present. The unburned or partially burned hydrocarbon flows through the gass collection system into the catalyst converter. Here the temperature is about 820°F and may go up to 1000°F. This is within the ignition limit of some hydrocarbons.

Ignition in the converter occurs resulting in the formation of CO_2 and water. This produces water in the area where it is not desired since the SO_3 conversion should be done with dry gas for maximum efficiency. In addition, the "mud" can coat the catalyst and other portions of the system before the converter, particularly heat exchanger surfaces.

It would appear highly desirable to first inject cooling water as far downstream from the sinter machine hood as possible to maximize the temperature of the offgases in and adjacent to the ignition area. This will allow time and temperature for the reaction of the hydrocarbon to CO_2. Secondly, some means should be provided to increase the temperature of the ignition offgases, perhaps with an auxiliary burner, to promote oxidation of hydrocarbon. In one case, where no mud like deposits are encountered the ignition layer is ignited by six steam ejected fuel oil burners. A third approach would be to inject oxygen at this point to further promote the reaction of the hydrocarbon by raising the temperature of the gas and providing an excess oxygen environment. Existing plants do seem to be able to operate with this problem, even though it does require some maintenance effort. Furthermore, the experience at one smelter implies that almost complete elimination of the black material is possible with high temperature ignition zone and no water injection near the sinter machine.

Acid manufactured from lead sinter machine gases tends to be black. It is believed that this black or, in some cases, straw color results from colloidal carbon that comes through the system also due to the flotation reagent. This material has been noted for many years and is more in the form of a dye, which is extremely difficult, if not impossible to move. This then somewhat limits the market for the acid produced since some users such as food manufacturers require clean "white" acid. However, the markets for fertilizer and leaching acids which can accept "black" acid are the major expanding markets at the present time.

The "water balance" problem in the acid plant has been encountered by some operators particularly in the summer time. This means that the water used for spray cooling plus whatever water is generated from the reaction of the flotation reagent, results in more water in the acid plant system than is needed to make either 93 or 98% acid. This problem can be easily cured by reducing the temperature of the SO_2 gas stream to a point where sufficient water has been eliminated. This has been shown in the curves of Figure 5 which are based on saturation conditions. If this cannot be done with conventional heat exchangers, refrigeration to reduce the temperature of the gas to as low as $40^{\circ}F$ can be provided. This approach has been used in Japan and is discussed in Reference 6. SO_2 concentrations as low as 1.5% sent directly to an acid plant can be tolerated with reduced feed temperatures.

It is extremely important to clean the particulate and acid mist from the SO_2 gases as soon after they leave the sinter machine as possible. High temperature ($600^{\circ}F$-$700^{\circ}F$) precipitators immediately downstream of the sinter machine appear to make the best match for reducing most of the particulate. Baghouses immediately downstream of the sinter machine introduce the problems of gas cooling, corrosion and bag blinding.

Mist precipitators and mist eliminators have been used to reduce the sulfuric acid mist which is caused by mixing of all small percentage of SO_3 formed with water vapor. As long as no acid mist is present, no corrosion will occur and mild steel material can be used for construction of the acid plant. In one case, a Venturi scrubber has been placed downstream of a precipitator to improve the mist collection.

Conventional mist precipitators and baghouses have been used and work satisfactorily. Considerable maintenance is required both for the baghouse and the precipitator. Problems of the baghouse include plugging and tears of the bags and usual replacement of the bags within one year, which is approximately one half of the "normal" bag life. Iron sulfate and sulfuric acid tend to cement dust with resultant blinding. The mist precipitator tends to get a buildup of material at the bottom of the tubes and these must be cleaned frequently (weekly) to maintain precipitator efficiency. High capacity, multiple mist precipitators are beneficial to allow alternate on time and maintenance.

Additional steps that can be taken to improve acid plant operations basically involve enhancement of the sulfur dioxide conversion to sulfur trioxide as follows (Reference 7):

- Reduce the initial sulfur dioxide concentrations entering the converter
- Reduce the ratio of SO_2 to O_2
- Increase the number of converter stages
- Increase the volume of catalyst
- Change catalyst more frequently and improve distribution
- Improve uniformity of feed conditions
- Reduce feed gas impurities
- Provide additional interstage cooling in converter and improve temperature control throughout the plant
- Reduce throughput rate
- Exercise additional care during plant start-up

Most of these steps tend to increase costs and therefore, must be considered in relation to the overall plant performance.

Since intermittent operation of the sinter machine cannot be avoided and since the conventional acid plant operates more efficiently and with less maintenance problems on a continuous basis, it appears that some method should be introduced to provide an auxiliary SO_2 source when the sinter machine is not producing. This approach is somewhat beyond the scope of this study and cannot be considered "current state of the art" but should be considered to minimize the intermittent SO_2 supply problem. The Cominco lead smelter is using an ammonium hydroxide with SO_2 reaction which eventually produces ammonium sulphate and concentrated SO_2 which is then sent to the acid plant (Reference 8).

Concentration schemes such as Wellman-Lord (Reference 9) or the ASARCO DMA can be used to produce liquid SO_2 that can be conveniently stored for use when the sinter machine is down. DMA concentration and production of liquid SO_2 has been conducted by ASARCO from lead sinter machine gases at the Selby Smelter.

Another alternative to obtain constant acid plant operation is to use a sulfur burner to generate SO_2 and heat when the sinter machine is not producing maximum acid plant feed. This scheme would allow the use of lower percentage concentrations of SO_2 in the feed gas as well as provide for complete sinter machine shutdown. Additional SO_2 and heat facilities autogeneous operation in the converter at a lower concentration. Ignition and turndown ratio (4:1 maximum in some cases) of the sulfur burner are possible problem areas unless it can be operated at a continuous fixed level.

The additional capital costs of the auxiliary systems would be partially returned by the reduction in acid plant size. With any auxiliary system only part of the sinter machine offgas stream would go to the acid plant with the remainder to the auxiliary supply system. A 75% sinter machine on time with 100% SO_2 (availability storage or generation) will allow a 25% reduction in acid plant size and provide a system with constant or more normal acid plant operation.

It should again be noted, that intermittant operation of acid plants can be and is currently being accomplished without auxiliary systems. However, more constant operation of these plants will improve sulfur capture efficiency and minimize maintenance. Furthermore, availability of a supply of SO_2 to increase concentration will allow the use of a double contact acid plant with its considerable reduction in emissions compared to the single contact plant.

VI. SO_2 CONTROL FOR ASARCO LEAD SMELTER, EAST HELENA, MONTANA

A. SO_2 Control System

There are perhaps a total of as many as 100 different methods for SO_2 control, if all modifications of basic systems are included, References 10 and 11. These systems may be divided into two major categories:

1. Primary systems for conversion of SO_2 to a saleable or throwaway product.

2. Secondary or concentrating systems.

The Type 1 SO_2 control systems may be classified as those systems that can handle relatively high percentage of SO_2 from approximately 3% up to as high as 18%. The Type 2 systems are essentially concentration systems that will increase extremely low percentages of SO_2 from 0.1% up to 3% to the point where the Type 1 systems can be used. There are some Type 2 systems that do produce a useful product such as the ammonium hydroxide system that can produce ammonium sulfate fertilizer along with a concentrated stream of SO_2. Table 4 lists some of these systems.

B. SO_2 Control for East Helena Lead Smelter

Since all operating lead smelters in North America have used either the "tall stack" or the sulfuric acid route for SO_2 control (Section IV) an acid plant can be considered as "reasonably available technology." The following discussion will therefore, review the use of a sulfuric acid plant applied to the East Helena, Montana lead smelter. As discussed in Section III the single contact sulfuric acid plant can operate on an SO_2 concentrated stream of approximately 3.5% to 8%. Too low a concentration requires additional heat to be supplied for SO_2 to SO_3 conversion and to high a concentration requires an excessive increase in heat exchange surface. It is therefore, desirable to adjust the stream coming from the sinter machine to increase the SO_2 concentration from the present 2.9% to 5-6%.

TABLE 4

Typical SO_2 Concentration Systems

- ASARCO DMA System (Dimethylaniline)
- Cominco (Ammonium Sulfite-Bisolfite)
- Wellman Lord (Sodium Sulfite)
- Lurgi Sulphidine (xylidine)
- Imperial Chemical Industries (Aluminum Sulfate)
- Magnesium Oxide (Magnesium Sulfite)

C. Degree of SO_2 Control Expected with Acid Plant

Total sulfur in the concentrates entering the lead smelting plants will vary from 14% to 33% throughout the industry. Generally 80-85% of the total sulfur entering the lead smelter as concentrate will be emitted as SO_2 from the sinter machine. An additional 7% will leave in the form of slag, stored sinter or dross. The remaining will leave from the blast furnace either as gas or fixed in the solid material. The 1971-1973 ASARCO records show that 92% to 94% of the total sulfur entering the smelter was emitted as SO_2 from the sinter machine (Reference 17)

The sulfur content in the total material processed by the sinter machine will vary from 4.5% to 7.0%. This is controlled to obtain proper flame temperature so that the desired physical characteristics of the sinter will be obtained. The sinter machine feed will be a mixture of initial concentrates, slags, fluxes, and recycled sinter. Generally the recycled material will be approximately 50-60% of the total sinter machine feed although in one case it is as high as 83% because of high sulfur content in the concentrates.

With no recirculation or limited recirculation of the weak SO_2 stream and processing of only the rich stream in the acid plant, typically 64% of the smelter input sulfur will be converted to sulfuric acid. 6% of the input sulfur will be fixed in solids resulting in a combined typical total of 70% sulfur capture.

With complete recirculation of the weak stream sinter machine gases (e.g. the use of only a single offgas stream from the sinter machine) as much as 86% of the smelter input sulfur has been captured as sulfuric acid with a single contact acid plant, (Section IV and Appendix). With the additional sulfur captured in the slag, etc. a maximum 90% overall input sulfur capture can be expected. The plant has a high (30%) sulfur content in the concentrate which would tend to show the potential for ASARCO at 23% sulfur content (both values are higher than normal - Table 2). Thus, the range of sulfur capture from no recirculation to full recirculation (partial is possible) should be from 70% to 90% as reasonable values. Plant operating conditions and condition of equipment will, of course, also be of significance in determining overall sulfur capture.

D. East Helena Smelter Plant Flow Sheet

Figure 12 shows a schematic plant flow sheet of the American Smelting and Refining Company, East Helena Smelter, East Helena, Montana. The concentrated ore, coke, scrap iron, purchased dross, siliceous ores and lime rock are brought into the plant by rail. The first step in the process is to prepare a feed for the blast furnace. The concentrates, coke - breeze, siliceous ores and lime rock are mixed to make up the sinter machine feed and pass through an impactor and nodulizing drum to provide thorough mixing and proper physical characteristics.

Primary feed from the nodulizing drum is then fed into a pelletizing drum along with recycled sinter that has passed through the sinter machine product classification system. This recycle sinter is primarily fines not suitable for the blast furnace. The total pelletized mix is fed onto the 8' by 72' updraft sintering machine (activated bed dimensions).

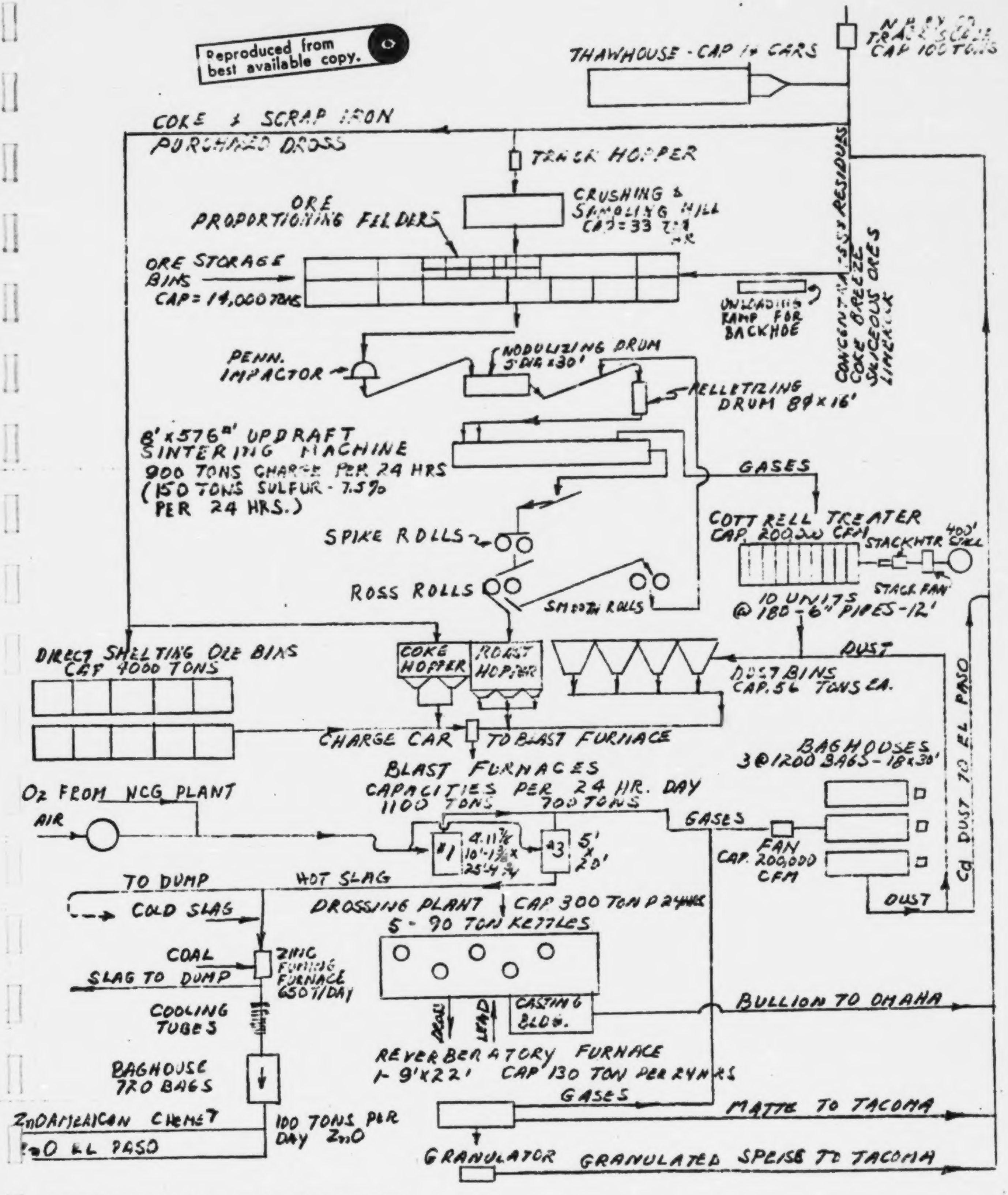
Material from the sinter machine is fed to a series of classification roles to separate the acceptable sinter material and the fines. Blast furnace feed consists of the sinter from the sinter machine, coke, recycled dust and direct smelting ores. Two blast furnaces are used.

The sinter machine offgases have water injected directly above the hood and also in a spray chamber following the hood to reduce the temperature to 175°F. They then pass to a Cottrell precipitator which cannot operate above 175°F. This unit has 180 six inch diameter by 12' long pipes.

After the gases have had the acid mist and particulate removed in the precipitator they are heated to approximately 250°F to raise the temperature above the dew point. The gases must be raised to 250°F for sufficient margin above the dew point because the 400' stack is concrete lined and cannot withstand any acid environment. The heating also aids in updraft.

The blast furnaces convert the lead oxide to lead. The hot material from the blast furnace enters the drossing plant where there are five 90 ton kettles. These kettles are used to separate the dross from the lead. The

Reproduced from best available copy.


THAWHOUSE - CAP 14 CARS
N.P.RY. CO. TRACK SCALE CAP 100 TONS
COKE & SCRAP IRON
PURCHASED DROSS
TRACK HOPPER
CRUSHING & SAMPLING MILL CAP=33 T/HR
ORE PROPORTIONING FEEDERS
ORE STORAGE BINS CAP=14,000 TONS
UNLOADING RAMP FOR BACKHOE
CONCENTRATES RESIDUES
COKE BREEZE
SILICEOUS ORES
LIMEROCK
PENN. IMPACTOR
NODULIZING DRUM 5' DIA x 30'
PELLETIZING DRUM 8Ø x 16'
8' x 576" UPDRAFT SINTERING MACHINE
900 TONS CHARGE PER 24 HRS
(150 TONS SULFUR - 7.5% PER 24 HRS.)
GASES
SPIKE ROLLS
ROSS ROLLS
SMOOTH ROLLS
COTTRELL TREATER CAP. 200,000 CFM
STACK HTR
400' STACK
STACK FAN
10 UNITS @ 180 - 6" PIPES - 12'
DUST
DIRECT SMELTING ORE BINS CAP 4000 TONS
COKE HOPPER
ROAST HOPPER
DUST BINS CAP. 56 TONS EA.
CHARGE CAR
TO BLAST FURNACE
BLAST FURNACES
CAPACITIES PER 24 HR. DAY
1100 TONS
700 TONS
#1
4.11⅞ 10'-1⅜ x 25'-4¾
#3
5' x 20'
O2 FROM NCG PLANT
AIR
GASES
FAN CAP. 200,000 CFM
BAGHOUSES 3@1200 BAGS - 18x30'
DUST
Cd DUST TO EL PASO
TO DUMP
HOT SLAG
COLD SLAG
DROSSING PLANT
CAP 300 TON P 24 HRS
5 - 90 TON KETTLES
COAL
ZINC FUMING FURNACE 650T/DAY
SLAG TO DUMP
COOLING TUBES
BAGHOUSE 770 BAGS
ZnO AMERICAN CHEMET
ZnO EL PASO
100 TONS PER DAY ZnO
DROSS
LEAD
CASTING BLDG.
BULLION TO OMAHA
REVERBERATORY FURNACE
1 - 9' x 22' CAP 130 TON PER 24 HRS
GASES
MATTE TO TACOMA
GRANULATOR
GRANULATED SPEISS TO TACOMA

AMERICAN SMELTING & REFINING CO
EAST HELENA SMELTER
EAST HELENA, MONT.

PLANT FLOW SHEET

FIGURE 12

lead is then cast in suitable shape (bullion) for shipment.

Separate operations for zinc fuming to produce zinc oxide and additional smelting in a reverberatory furnace for preparation of speiss also take place within the smelter. Gases from the blast furnace, drossing plant and reverberatory furnace all pass through three baghouses. The dust collected in the baghouses passes back to dust bins and is used as part of the feed for the blast furnace (or separated as a useful product for shipping for further refining).

E. Sinter Machine System

The primary source of SO_2 at the plant is the sinter machine. This machine has an active bed 8' wide and 72' long. Its total length is 100' with the capability of handling a process weight of at least 2200 TPD at 7.5% sulfur content.

A schematic of the sinter machine system is shown in Figure 13. The ignition system consists of one downdraft bed with one windbox and fan handling approximately 5,940 CFM. The gases from the ignition bed are vented from the windbox hood through vent fan to the stack.

The 72' long active bed has nine updraft windboxes with basically three air feed systems. Windbox 1 and 2 are fed by fan #1 handling 17,700 SCFM. Windboxes 3, 4, 5 and 6 are fed by #4 fan handling 29,100 SCFM. Windboxes 7, 8 and 9 are fed by #3 and #2 fans at 33,350 SCFM.

The flow rates shown in Figure 13 are estimates for various parts of the sinter machine system based upon the data in reference 3, and the information obtained during the visit to the smelter (Appendix). The flow rates in SCFM can only be considered approximations because the plant flows are continuously adjusted during operation to obtain desired metallurgical properties of the sinter.

As can be seen, partial recirculation of the oxygen richer gases from the downstream end of the sinter machine is obtained. Approximately 19% of the total flow in SCFM leaving the sinter machine is recirculated.

The top hood of the sinter machine has water spray heads at the down-

EAST HELENA SINTER [illegible] SYSTEM 1974

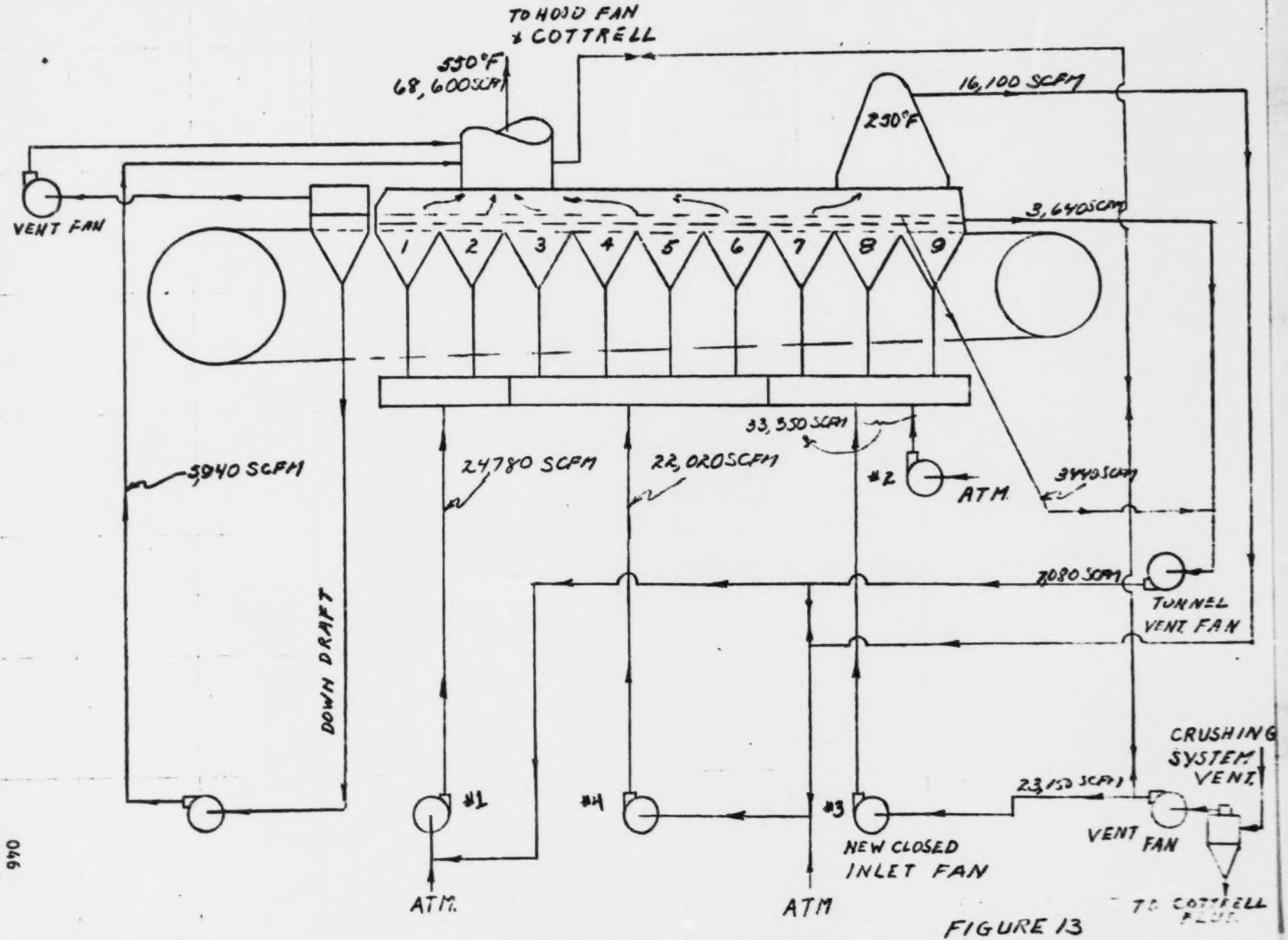

TO HOOD FAN
& COTTRELL
550°F
68,600 SCFM
16,100 SCFM
230°F
3,640 SCFM
VENT FAN
1
2
3
4
5
6
7
8
9
33,550 SCFM
5940 SCFM
24,780 SCFM
22,020 SCFM
#2
ATM.
3440 SCFM
7080 SCFM
TUNNEL
VENT FAN
DOWN DRAFT
CRUSHING
SYSTEM
VENT
23,150 SCFM
#1
#4
#3
NEW CLOSED
INLET FAN
VENT FAN
ATM.
ATM
TO COTTRELL
FLUE

FIGURE 13

stream end placed approximately 4' apart on both sides of the machine to cool the gases. Vented air from the sinter machine tunnel and the crushing system is recirculated back to the sinter machine. During operation the system is adjusted to provide sufficient air, bed depth, machine speed, dust collection and metallurgical characteristics of the sinter.

At present this is being done simply by adjusting the airflow through the various windboxes and the physical location of the downstream exhaust takeoff point in relation to the main stack. Typical temperatures leaving the machine at the main duct are 550°F and at the downstream recirculating duct of 250°F. Cooling of the gases is accomplished by water spray injection at the sinter machine hood in the downstream end of the sinter machine.

F. Sinter Machine Sulfur Elimination

The sulfur elimination curve showing percent SO_2 versus length along the main sinter bed is shown in Figures 14 and 15 taken from Reference 3. The absolute values of percent SO_2 will vary, depending upon the various operating conditions such as airflow at the various windboxes, sulfur concentration in the bed, speed of the machine, thickness of the sinter bed, lead percentage and particle size distribution. As can be seen, the first 40 feet of the machine emits the major portion of the SO_2.

The SO_2 average concentration was measured and determined to be 2.81% for curve Figure 14, and 2.99% for curve Figure 15. A numerical integration of these curves Table 5 results in an average SO_2 content of 3.58% (compared to measured 2.99%). The average of the integrated value is 2.66% and the measured value 2.90%.

The difficulties in taking measurements and the variation in the operating conditions above the sinter bed make the data spread somewhat large and therefore, the agreement is considered reasonably good.

G. Modification of Sinter Machine System For Increased SO_2 Concentration

The SO_2 concentration can be increased by separation of the high and low concentration streams out of the sinter machine with recirculation of the low SO_2 stream. Recirculation of low SO_2 concentration stream was

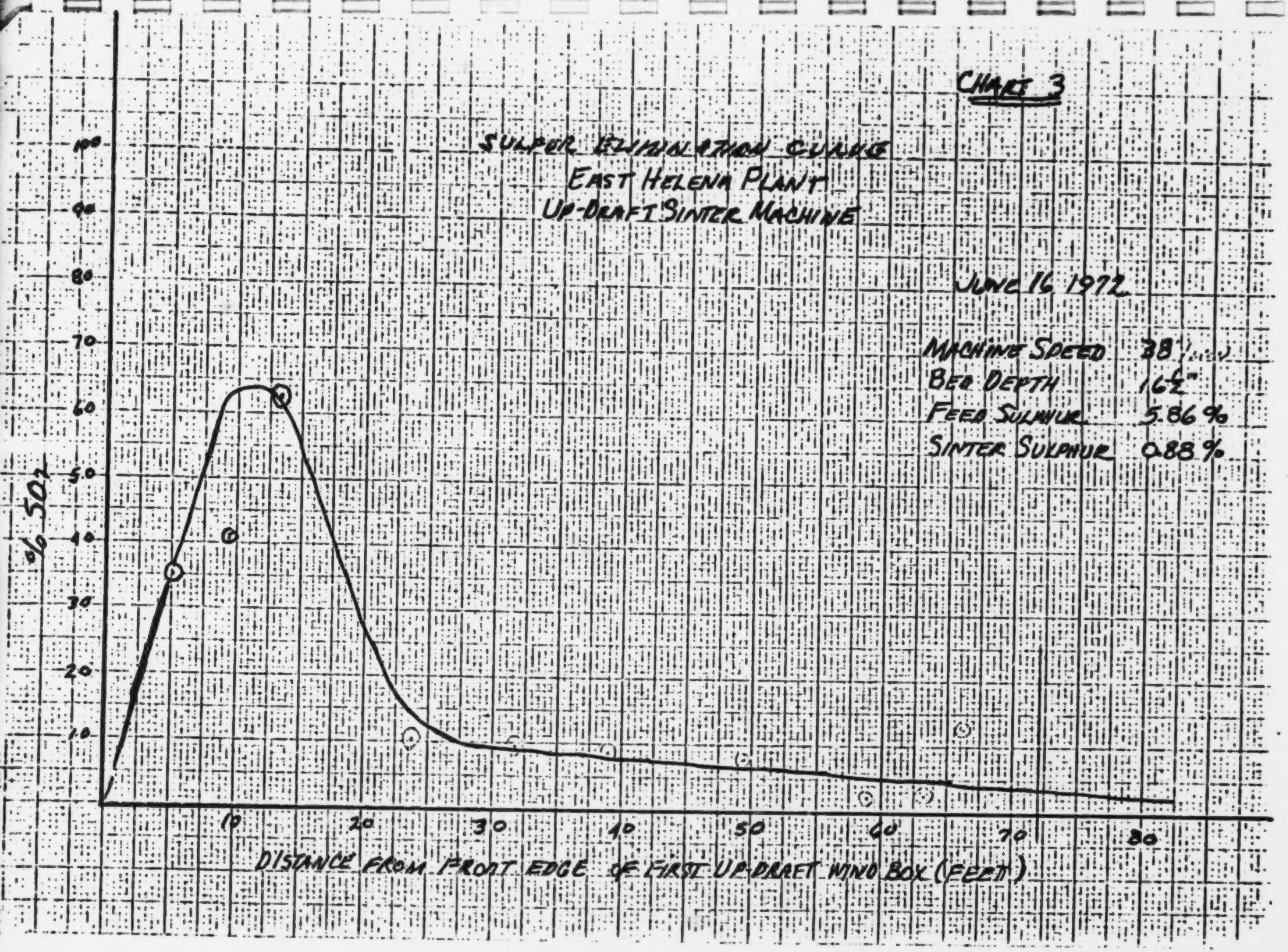


CHART 3

SULPER ELIMINATION CURVE
EAST HELENA PLANT
UP-DRAFT SINTER MACHINE

JUNE 16 1972

MACHINE SPEED 38' [illegible]
BED DEPTH 16½"
FEED SULPHUR 5.86 %
SINTER SULPHUR 0.88 %

FIGURE 14

KEUFFEL & ESSER CO.

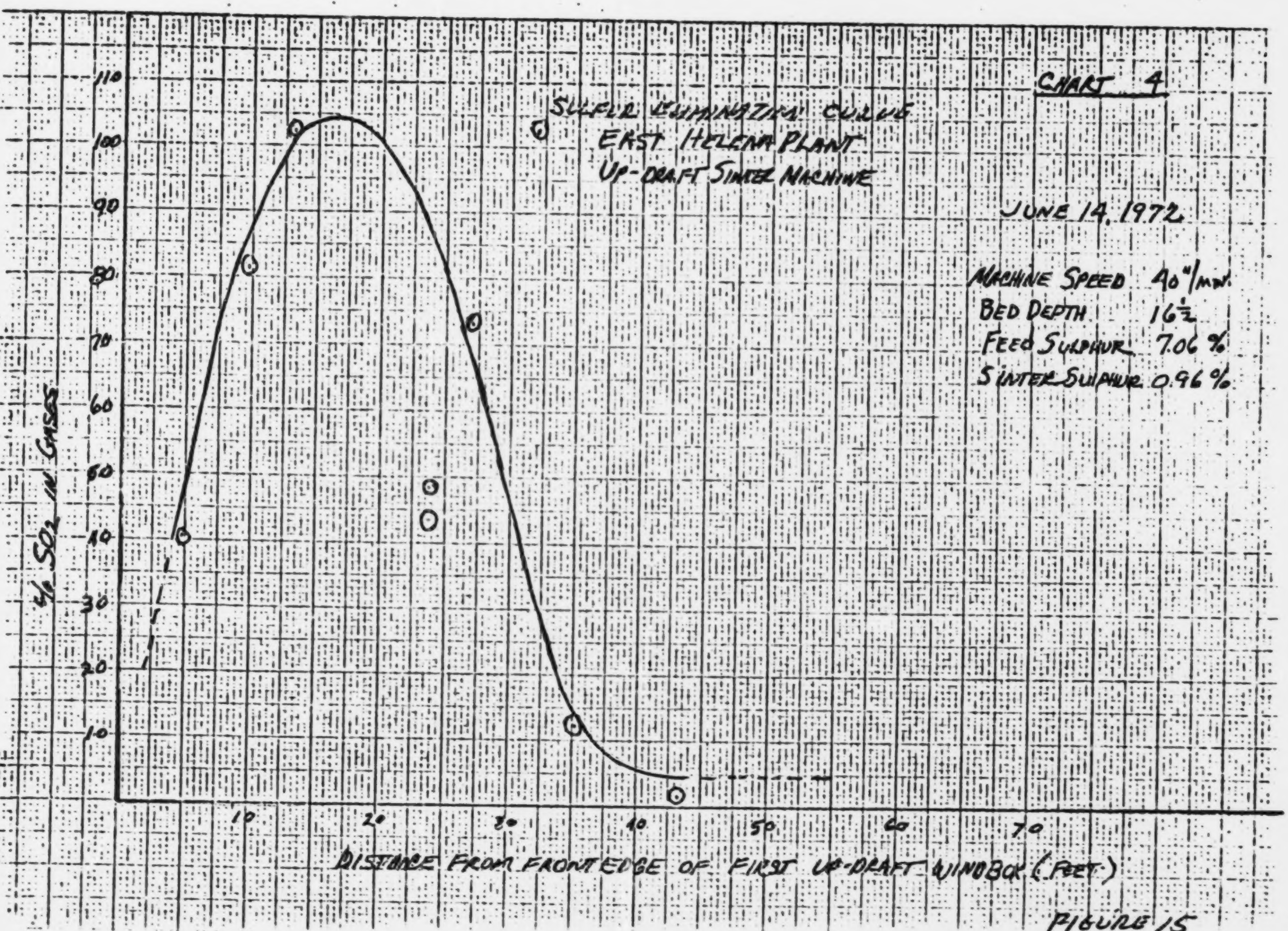


CHART 4

SULFUR ELIMINATION CURVE
EAST HELENA PLANT
UP-DRAFT SINTER MACHINE

JUNE 14, 1972

MACHINE SPEED 40"/MIN.
BED DEPTH 16½
FEED SULPHUR 7.06 %
SINTER SULPHUR 0.96 %

FIGURE 15

TABLE 5

SULFUR ELIMINATION CURVE INTEGRATION

CHART 3

POSITION L-FT.	SO_2 %	POSITION L-FT.	SO_2 %	POSITION L-FT.	SO_2 %
2.5	1.7	27.5	1.0	52.5	.6
5.0	3.5	30.0	.9	55.0	.6
7.5	5.2	32.5	.9	57.5	.55
10.0	6.3	35.0	.85	60.0	.5
12.5	6.3	37.5	.8	62.5	.5
15.0	5.4	40.0	.8	65.0	.4
17.5	4.1	42.5	.75	67.5	.4
20.0	2.7	45.0	.7	70.0	.38
22.5	1.75	47.5	.7	72.5	.35
25.0	1.25	50.0	.65		

SO_2 MEAN $= \frac{50.53}{29} = 1.74\%$

SO_2 MEAN MEASURED = 2.81%
(REFERENCE 3)

CHART 4

POSITION L-FT.	SO_2 %	POSITION L-FT.	SO_2 %	POSITION L-FT.	SO_2 %
2.5	2.5	27.5	6.4	52.5	.45
5.0	4.95	30.0	4.6	55.0	.45
7.5	7.25	32.5	2.8	57.5	.45
10.0	8.80	35.0	1.5	60.0	.40
12.5	9.9	37.5	.8	62.5	.40
15.0	10.4	40.0	.6	65.0	.40
17.5	10.4	42.5	.5	67.5	.40
20.0	10.1	45.0	.48	70.0	.40
22.5	9.3	47.5	.46	72.5	.40
25.0	8.0	50.0	.45		

SO_2 MEAN $= \frac{103.9}{29} = 3.58\%$

SO_2 MEAN MEASURED = 2.99%

SO_2 AVERAGE OF INTEGRATED VALUES $= \frac{1.74 + 3.58}{2} = 2.66\%$

SO_2 AVERAGE MEASURED $= \frac{2.81 + 2.99}{2} = 2.90\%$

conducted by ASARCO as early as March 1914. This work was done at their California Selby Smelter. Additional tests on recirculation were carried out at Trail and at Kellogg, Idaho smelters. This work is summarized along with preliminary and commercial experience with recirculation in Reference 12. While most of the work was done with a downdraft sinter machine and most present smelters have updraft, it did conclusively prove that recirculation did provide an increase in the SO_2 concentration.

Separation of the rich stream as seen from the sulfur elimination curve Figure 14 such that only this stream will go to the acid plant will materially increase the SO_2 percent. For example, a step by step integration of the sulfur elimination curve assuming the stream going to the acid plant is taken from the first five windboxes, (covering the initial 40' of the sinter machine) results in an SO_2 concentration of 6.14%. (If this is corrected to adjust for the difference between the integration and the actual measurement, this percentage would reduce to 5.3%).

In addition, the total gas volume going to the acid plant would be 41,295 SCFM if the downdraft ignition stream is included. Thus, 64.5% of the gas being emitted from the sinter machine would go to the acid plant and 36.5% would be recirculated. It should be emphasized that the exact numbers in this case are only representative, and are used as an indication of what can be done with this particular equipment. Actual smelter experience (Appendix and Section VI) indicates that this is a practical method of operation under the proper conditions. Experience with the specific equipment and feed material is required to determine optimum operating conditions.

Furthermore, it appears that a significant reduction in total air flow (with consequent increase in SO_2 concentration) is possible. One smelter uses a total air flow of 50,000 SCFM to process approximately 600 TPD of 33% sulfur rich concentrate. This compares with nearly twice this amount of air with approximately 700 TPD of concentrate at 23% sulfur at East Helena. (The other smelter has a larger machine so the data are not directly comparable but indicative only).

A potential problem that may be encountered with recirculation is lack of available oxygen. This can be corrected by so-called oxygen enrichment providing an external supply of additional oxygen is available. The development of this technique again must be done for each particular sinter machine operation and will take some development effort to obtain a satisfactory system. Particular care must be taken to minimize excessive temperatures and hot spots when oxygen is used. In a two windbox downdraft system early recirculation experiments resulted in the actual extinguising of the burning of the sinter because of lack of oxygen. In addition, if sufficient oxygen is not present it is possible to obtain elemental sulfur which can be passed throughout the entire downstream system causing contamination problems.

H. Sulfuric Acid Manufacture Capability At East Helena

Based upon current thruput it appears that a 400 TPD sulfuric acid plant should be capable of handling the maximum amount of SO_2 generated at East Helena. See Table 6.

I. Required Minimum Existing Plant Modifications

If it is assumed that the minimum effort be expended on plant modifications and equipment additions, the basic approach to SO_2 control at East Helena would be to install a gas cleaning system and a single contact sulfuric acid plant to handle rich SO_2 stream gases from the existing sinter machine. Lean stream gases would be passed to atmosphere. Experience has indicated that a maximum effluent SO_2 concentration of 2000-2600 ppm can be maintained under these conditions.

The following major plant modification steps would be required:

- Partial removal of existing brick duct to existing precipitator.
- Install hot gas precipitator and its output dust handling system.
- Connect sinter machine hood outlet duct to hot gas precipitator
- Install scrubbers, cooling tower, mist precipitators and associated ductwork and fans.
- Install remainder of single absorption sulfuric acid plant with product storage tanks.
- Reconnect remainder of dust emission points to existing precipitator. (Replacement of this precipitator with a modern unit is certainly adviseable).

Table 6. Sulfuric Acid Potential at East Helena, Montana Smelter

	1971	1972	1973
Sulfur input to plant, TPY*	51,728	49,329	40,753
Operating days*	319.8	320.8	314.2
Sulfur input to plant TPD	161.8	153.8	129.7
Sulfuric acid (100%) potential TPD	494.8	470.3	396.6
Maximum expected sulfuric acid 100% production TPD (80% plant input S from sinter machine to acid plant)	395.8	376.2	317.3

* Data received from EPA (6-4-74)

Additional development effort to improve the gas supply system to the sinter machine should materially improve operations. Significant reduction of the total air flow through the sinter machine appears possible considering experience at other smelters.

J. Compliance Schedule

Procurement of a single contact acid plant in the 400 TPD size range is shown by major steps in Figure 16. These estimates were obtained from References 13, 14 and 15. (Appendix).

Completed plant, including start-up, can be supplied in 25 to 31 months. The largest delay or rate determining step at this time is in the procurement and fabrication of steel platework. Availability of steel has extended plant procurement times by as much as 12 to 14 months. This situation cannot be predicted but some improvement has recently been noted. Purchased items such as electric motors that normally are stock items are also not readily available at this time.

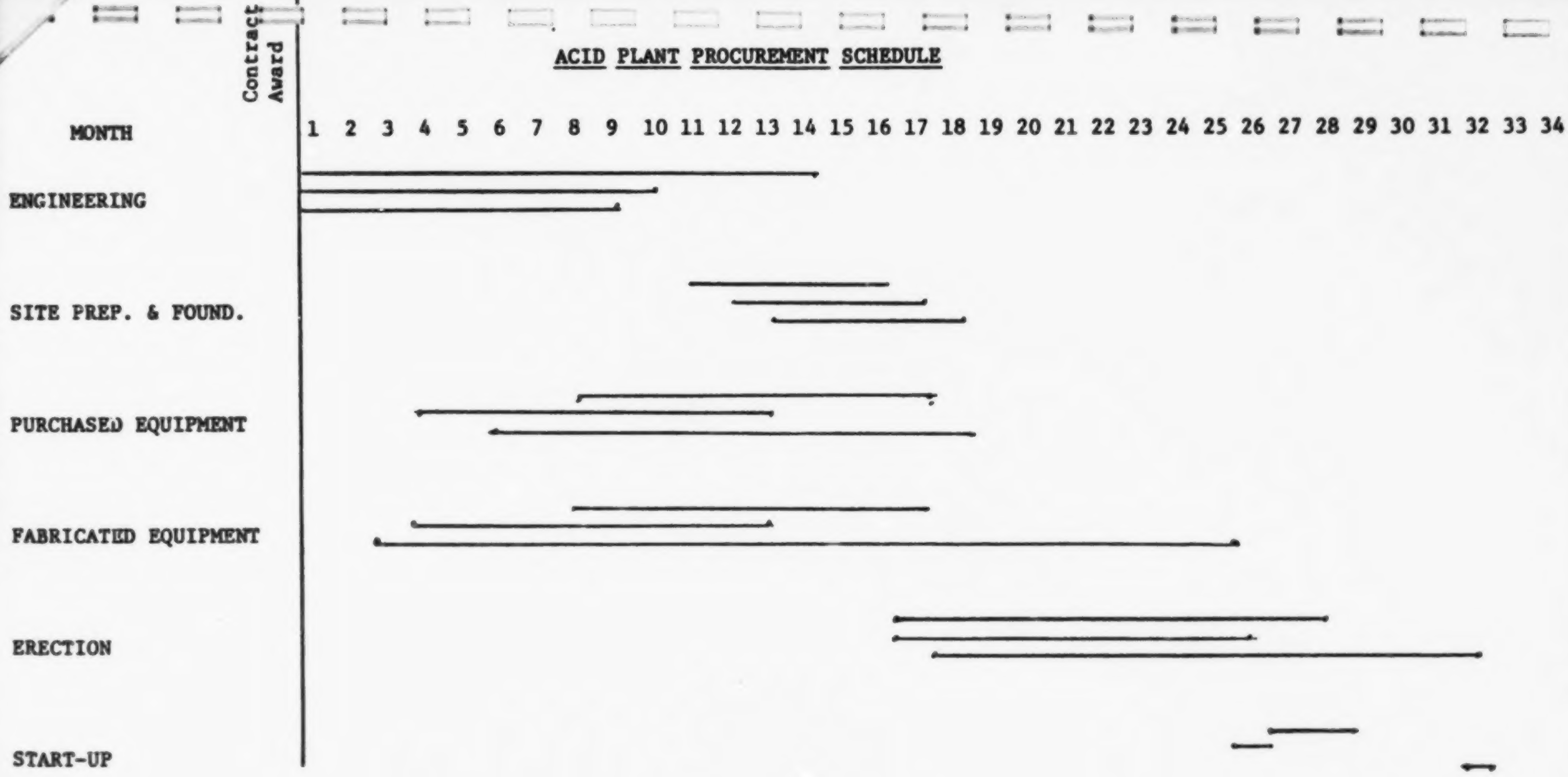
Gas cleaning equipment such as precipitators and scrubbers can be obtained in the same time period and are influenced by the same constraints as the acid plant.

Assuming installation of a single absorption acid plant with its associated gas cleaning system at East Helena and using existing water, power and fuel systems the increments of progress are shown in Table 7. Starting July 1, 1974 it is expected that the new system can be in normal operation by November 1, 1977. This allows a three month "shakedown" to phase operation of the new equipment with the rest of the plant.

K. Cost Estimate

Wide ranges of costs for a sulfuric acid plant can be obtained depending upon the minimum input of SO_2 concentration (converter size), the maximum temperature of the cooling water for the heat exchangers (heat exchange surface) and the degree of gas cleaning carried out (particulate collector size). In addition, special design features, such as parallel mist precipitators, can be included to minimize maintenance downtime by

ACID PLANT PROCUREMENT SCHEDULE



NOTE: Each line represents a different vendor estimate
3 vendors supplied information (not in this order)

Monsanto Envirochem

Ralph L. Parsons

Chemical Construction Co.

FIGURE 16

TABLE 7

COMPLIANCE SCHEDULE

ASARCO - E. HELENA, MONTANA LEAD SMELTER

INCREMENTS OF PROGRESS:

Date of Submittal - final control plan	11-4-74
Date of Contract Award for Equipment	2-3-75
Date of Initiation of On-Site Construction	1-5-76
Date of Completion of Equipment Installation	8-1-77
Date of Final Compliance	11-1-77

ASSUMPTIONS:

1. A complete new gas cleaning system will be installed to handle gases from sinter machine.
2. A single absorption acid plant will be used.
3. Acid plant design will be subcontracted.
4. Gas cleaning system consists of (in order used)
    a. Hot gas precipitator
    b. Scrubber - cooler
    c. Mist precipitator
5. Existing water, power and fuel systems can be used.
6. Work initiated July 1, 1974.
7. Steel plate continues in short supply.

providing by-pass modes of operation to allow removal of components from the system during operation.

As an estimating range, the single absorption plant in the 400 TPD range will cost $4,000,000 to $5,000,000. Gas cleaning systems will range from $5,000,000 to $6,000,000 and will be dependent upon gas volume flow which can be minimized by sinter machine operating techniques. Total capital costs should range from $9,000,000 to $11,000,000. With possible escalation this would result in a maximum estimate of $11,000,000 to $12,000,000.

Operating costs exclusive of depreciation have been estimated at $7.00 to $13.00 per ton of acid, based on vendor and operator estimates. The plant can be depreciated over a 15 year period resulting in approximately a $9.00/T additional cost. Maximum cost of acid could be as high as $22/T.

A double contact acid plant would increase acid plant cost by approximately 10%. Refrigeration to increase cooling efficiency for further moisture removal would increase acid plant cost by 15%.

L. Space Requirements

An acid plant in the 600TPD size range can be designed to the following overall dimensions (Reference 14):

Acid Making System	77' x 200'
Gas Cleaning System	46' x 200'
Elevation Maximum Less Stack	70'

It would be expected that a 400 TPD plant would use somewhat less space such as:

Acid Making System	70' x 190' = 13300 sq. ft.
Gas Cleaning System	44' x 190' = 8350 sq. ft.

Because the plant is composed of many components the arrangement of the major items is somewhat flexible in terms of the overall plan geometry. The gas cleaning system should be located as close to the sinter machine as possible and the acid making section as close to this as possible.

Based on preliminary information there appears to be 70' x 300' available adjacent to the sinter machine at East Helena for the acid plant. Additional space 40' x 300' appears available beyond this. The estimated 21,650 sq. ft. required could be arranged within the available space if the existing brick flue is removed.

VII. REFERENCES

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7. Air Pollution Control Field Operations Manual, TM-4870/000/00, Control Agency Procedures Branch, Office of Air Programs, EPA, February, 1972.

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11. "Controlling the "Other" Sulfur Oxides Sources" K. Semrau, 167th ACS National Meeting April 4-5, 1974.

12. "Concentration of the SO_2 Content of Dwight-Lloyd Sintering Machine Gas by Recirculation" W.S. Reid, Metals Transactions pp 261-266, April, 1949.

13. Discussion with Mr. M.E. Doyle, Sales Manager, Process Plants, Monsanto Envirochem, St. Louis, Mo.

14. Discussion with Mr. T. Browder and Mr. R.E. Warner, Sulfuric Acid Process Managers, Ralph M. Parsons Co., Los Angeles, Calif.

REFERENCES (Continued)

15. Discussion with Mr. R. Berger, Chemico, New York, N.Y.

16. "Sulfuric Acid Production from Ore Roaster Gases" J.R. Donovan, P.J., Stuber, pp. 45-50, Jrnl. of Metals, November 1967.

17. "Environmental Impact Statement For The Air Pollution Variance Requested By: The American Smelting And Refining Company For Its East Helena Lead Smelter" Montana Department of Health and Environmental Sciences, May 20, 1974.

VIII. APPENDIX

Visit and telephone conversation notes

St Joseph Lead, Herculaneum, Mo.

Amax Lead, Boss., Mo.

Bunker Hill Smelter, Kellogg, Idaho

ASARCO Smelter, East Helena, Montana

Brunswick Smelting & Refining, Beladune,
New Brunswick, Canada

Monsanto Envirochem, St. Louis, Mo.

Ralph M. Parsons Co., Los Angeles, Calif.

Chemical Construction Co., New York, N.Y.

EPA Meeting Region VI

I. SUMMARY OF THE VISITS TO ST. JOSEPH LEAD SMELTER AMAX LEAD SMELTER MONSANTO CHEMICAL CORPORATION

The visits to the St. Joseph Lead Smelter at Hurculaneum, Mo. and the Amax Lead Smelter at Boss., Mo., were made to obtain experience data on the use of sulfuric acid plants for SO_2 control for a lead smelter. The visit to Monsanto Chemical Corporation, Envirochem Division, was made to obtain updated information on acid plant design as applied to lead smelters. A preliminary meeting at EPA Region VI offices in Kansas City was held and some detailed information on the smelters to be visited as well as the E. Helena Smelter was obtained.

In general, the experience at St. Joseph Lead indicated a very marginal operation of the acid plant as a result of most of the problems mentioned by ASARCO in the objections they have made to using acid plants on their lead smelters. However, all of these operating problems are the result of either not recognizing and allowing for them during the design phase or not modifying the smelter operation to match the acid plant requirements. It appears that the smelter (at least originally) did not recognize the acid plant problems and vice versa.

As further confirmation of the feasibility of applying an acid plant for SO_2 control for a lead smelter, the Amax Plant is operating with considerably less difficulty and while still having some problems, are able to operate very consistently to produce and market sulfuric acid. They are even considering adding to and increasing the capacity of their acid plant.

In both cases, a market is available to sell the acid product produced. However, St. Joseph is under a long term contract and cannot adjust their price to meet market conditions whereas Amax is able to raise prices as the market changes.

Monsanto confirmed the above and further indicated that making acid from lead smelter tail gases was more difficult than from other non-ferrous metal smelting because of the carbon coming through the system from the flotation reagent used to concentrate the ores. This carbon tends to react resulting in the formation of water which causes serious corrosion problems. They believe that an acid plant can be specifically designed for a lead smelter to solve the problems being encountered.

II. EPA, REGION VI MEETING

A meeting was held at EPA, Region VI offices in Kansas City, Mo., on April 23 to discuss SO_2 control for smelters, particularly the ASARCO plants at East Helena, Montana and Glover Mo. The following people attended:

Tom Jacobs, EPA, Region VI
Mike Sanderson, EPA, Region VI
Norm Huey, EPA Region VIII
Charles O'Boyle, EPA, Region VIII
Bud Weisenberg, PES

A general discussion of EPA position on SO_2 control indicated that dispersion control either by tall stacks or intermittant operation (ICS) was not considered acceptable by EPA as a long term solution to the problem.

Questions on the smelters raised by PES and Region VIII were discussed to get as much of the background from Tom Jacobs and the EPA, Region VI ASARCO files as possible. Considerable data from ASARCO (that neither Region VIII or PES had seen) was made available. Much of the significant data (i.e. cost studies on various control means for the East Helena Smelter) was taken by Norm Huey for duplication. He will send copies to PES and return to Region VI.

The St. Joseph Lead Smelter combines all streams from the sinter machine blast furnace, ventilation air and acid plant to one stack. (Approximately 400,000 SCFM). Tests were conducted indicating they were meeting 2000 ppm requirement at stack.

Amax has also conducted tests indicating they meet the 2000 ppm requirement. They have a sinter machine designed to recirculate the weak stream but have never operated this way.

III. ST. JOSEPH LEAD SMELTER, HURCULANEUM, MO

Attendees at the meeting after the plant tour were:

Tom Jacobs, EPA, Region VI
Bud Weisenberg, PES
Charlie O'Boyle, EPA, Region VIII
Maurie A. Pickard, St. Joseph Minerals Corp.
J.W. Sherman, Manager, St. Joseph Minerals Corp.
H.R. Bianco, Assistant Manager, St. Joseph Minerals Corp.
D.H. Beilstein, Chief Metallurgist, St. Joseph Minerals Corp.

R.T. Jacobs, Jr., EPA, Region VII
Byron Taylor, EPA, Region VII
Bruce Clark, Assistant Superintendent Acid
Plant, St. Joseph Minerals Corp.

The St. Joseph operation uses one sinter machine to feed one acid plant. They combine all off-gas streams to one stack with total flow of 550,000 SCFM. Data obtained follows:

- 550,000 ACFM to baghouse
- Concentrate 50-55% lead 15-16% sulfur
- On sinter machine - charge 1½ inches thick - 10% raw chg to ignition, 90% to burden

Burden Layer to 10 inches thick
Blast furnace charge 1600-1650 TPD 10.7%-11% coke

Concentrate Tons	CFM	% SO_2	Pb Tons	H_2SO_4
1268	27200	5.0	830	249
1263	34800	4.9	498	220

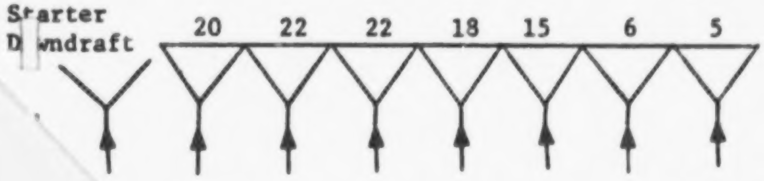
- Sinter plant time on always tends to be longer than acid plant time/on. Time difference ranged from zero to up to 4 hours for a one month study.
- Heat exchangers cause 8-12 hours acid plant shutdown/day.
- 40-120 BTU/Ft^2 average heat exchange rate for Carbate heat Exchangers.
  350 BTU/Ft^2 design - reduction due to fouling - 40 BTU/Ft^2.
-

	Design		Normal		Max.	
	TPH	TPD	TPH	TPD	TPH	TPD
Sinter	139 x 24 =	3336	146 x 24 =	3504	183 x 24 =	4392
Blast furnace	64 x 24 =	1536	68 x 24 =	1632	85 x 24 =	2040
Dross Reverb.	6 x 24 =	144	7 x 24 =	168	9 x 24 =	216

- Exhaust gas volume range 820,000 SCFM to 370,000 SCFM

Sinter Machine **St. Joseph Lead Smelter**

SO_2 and temperature curve



Pressure inches H_2O above atmospheric
13 updraft windboxes (all not shown)
16-20" H_2O at precipitator

- **Feed Mix**

Original Concentrate	72% Pb	17% Sulfur
After adding slag	72% Pb	16% Sulfur
After Adding Recycle (52%)	46% Pb	12% Sulfur
Slag consists of FeO, SiO_2, CaO		
Recycle sinter consists of	46% Pb	1% Sulfur

- Off-gas Mix
  Final sulfur content 12% (original because of dilution) + 1% (Sinter) ÷ 50% = 6.5%

  Water in gases to sinter plant 12% (added in part by cooling sprays over sinter bed).

- Requires 1/2 hour from start of sinter machine to build up to full SO_2 stream concentration.

- Sinter machine 10 ft. wide x 105 feet long

- Problems:

At St. Joe the problems of operating the acid plant in conjunction with the sinter machine has been extensive. These problems are listed as follows:

- High moisture content of gases.
- Flotation oil contamination
- Gaseous condensation after baghouse (sulfur)
- Water supply contains 1.5 ppm iron which tends to plug the inside of the heat exchangers.
- 93% acid requires a gas temperature of 93°-96°F which requires 1500 GPM for cooling
- There is approximately 1.2 lbs of oil in one ton of concentrate (flotation)
- 3.5 - 3.6% SO_2 required in the gas for autogenous operation.
- Heat exchangers have been completely retubed after 4-5 years of operation.
- Source of water is as follows:

4% moisture in the charge
Ambient air
Spray in water
Natural gas 70 CFM per ton of feed

- 40,000 wet SCFM to the acid plant which is equivalent to 32,000 DSCFM.
  120 lbs per minute water enters from the sprays
  270 lbs per minute water from the charge
- Gases are cooled to 150°F to enter the baghouse which uses acrylic bags. The baghouse is insulated.
- Considerable corrosion has been encountered around the baghouse screw conveyor and shaker mechanism. They have obtained only one year life on the bags.
- They are able to capture 80% of the sulfur from discharge from the sinter machine.
- 1400°F is required for the sintering temperature.
- They stated that about 50% of the sulfur goes to the acid plant.
- They need to minimize the amount of water in the acid on the sinter machine shutdown which requires shutting down the acid plant. It takes one half hour to ensure that the sinter machine is started before the main acid plant blowers are turned on. This blower is 1250 hp.
- There is not enough heat available from the acid plant to use in any part of the process.
- Iron sulfate condensation causes welding problems.
- They tried a fiberglass flue but this failed because it was not strong enough.

IV. VISIT TO AMAX LEAD SMELTER, BOSS. MO

Those present were the following:

R.C. Harban, Plant Manager
G.H. Carr, Environmental Engineer
Charles O'Boyle, EPA, Region VIII
Bud Weisenberg, PES

Two days per week (Tuesday and Thursday) are used for standard maintenance, for the sinter machine and acid plant. Maximum off time is 8 hours each day.

They have a 200 foot stack where the monitors are placed in strategic areas ensure meeting SO_2 requirements which the State of Missouri says they do meet.

They handle 40,000 SCFM total gases to the sinter machine. They handle 22,000 SCFM to the acid plant. The gas stream to the acid plant contains an average of 5.5% SO_2 with a range of 4.9 to 7.0%.

They have a Lurgi sinter machine. (22,000-25,000 SCFM to acid plant). The original acid plant was designed for 200 TPD and they are presently running at 240-250 TPD.

They do recirculate some of the cold gas. Gases coming off the upend of the sinter machine at 600°F and at 350°F off the cold end.

The gases leave the sinter machine and go to a spray chamber where 25GPM of water is sprayed in. The temperature drops from 600°F to 250°F.

They use 98% acid in the drying tower.

They estimate that due to maintenance problems sinter machine is on only 75% of the time. However, start and shutdown of the acid plant does not appear to be too serious a problem.

Bag life on the baghouse is one year.

Input concentration contains 70% lead and 15-15.5% sulfur.

The original cost of 200 TPD acid plant was $2,500,000. Operating cost here is approximately $718,000. (?)

At 52,000 TPY acid operating cost here is $13.83 per ton producing 94% acid. Added to this is approximately $5 per ton for depreciation.

One-sixth of the operating cost is extended in the annual 3-4 week shut-down maintenance for the acid plant. This maintenance includes the following:

- screening the catalyst bed.
- clean the cooling coils in the heat exchangers.
- clean out gas ducts of dust.
- mist precipitator maintenance.
- pack tower clean out (every two years)

- spray chamber repair and leak elimination

The acid plant manufacture guaranteed 96% conversion with the four pass converter. They are considering putting in a double contact plant.

They investigated the responsibility of using processes to clear up the black acid but have found that this is not possible to do without going to extensive cost. In addition, iron and lead may be present in this acid, eliminating its purchase by many users. They have also encountered plugging of the heat exchangers where they white sulfate material.

The total number of men operating the plant are 305. This processes 150,000 tons per year of lead with 1 oz of silver per ton and 50,000 TPY sulfuric acid. The pay scale is in the range of $2.55 to $4.65 per hour.

V. BUNKER HILL SMELTER, KELLOGG, IDAHO

A. Meeting with EPA, Region X and VIIIto discuss data from the Bunker Hill Smelter for Project 046.

A meeting was held at EPA Region X Headquarters in Seattle, Washington to obtain data on the Bunker Hill Smelter on May 5, 1974. The following people were in attendance:

EPA Region X:	Ben Eusebio Chuck Findley Dean Wilson (Regional Meteorologist)
EPA Region VIII:	Norm Huey C. J. O'Boyle
PES:	Bud Weisenberg

The PES work statement was reviewed. Region X personnel indicated that they were presently "negotiating" with the Bunker Hill Smelter on a new regulation and did not want any further EPA visits. They attempted to answer all questions. Some additional information was required specifically in the areas of operating problems encountered. EPA Region X will obtain this information and transmit.

During my discussion with N. Huey after the meeting I indicated and he agreed, that we should, if at all possible, talk to the people at Bunker Hill directly. This is particularly important because they have both zinc and lead smelters with acid plants. They have little or no problems with the acid plant on the zinc smelter, but considerable with the lead smelter. N. Huey will try to arrange. The following information was received on the Bunker Hill Smelter:

- Lead sinter machine 8 ft. wide x 96 ft. long.
- Water is not sprayed into sinter machine. Gas cooling done in separate spray chamber.
- They use their product acid in fertilizer plant.
- 79% of SO_2 is captured in acid plant.
- 70% of input sulfur is captured.
- They can hold heat in acid plant for 12-24 hours with auxiliary and no SO_2 flow.
- 732,000 TPY concentrate to lead smelter 40 oz/ton silver.

- 236,000 TPY concentrate to zinc smelter 6 oz/ton silver.
- Acid Plant Size = 300 TPD.
  Acid Plant Cost = $\$6.5 \times 10^6$.
- Gas stream diverted during acid.
- Answers to the list of questions (Attachment A) following Attachment B.
- Plant block diagram Attachment C.

B. Telephone Conversation with Mr. Gene Baker, Plant Engineer, Bunker Hill, Kellogg, Idaho, on May 20, 1974.

At the request of Mr. Norman Huey, Project Officer, Mr. Gene Baker, Plant Engineer of the Bunker Hill Smelter was contacted by telephone (area code 208-784-1261, Ext. 216).

The purpose of the call was to obtain additional information that was not available at the meeting with Region X people in Seattle.

The Bunker Hill Smelter Lead Sinter Machine has no water injection in the hood of the machine. Gases averaging 700°F pass from the hood of the sinter machine to the water spray chamber. The spray chamber reduces the temperature of gases to a minimum of 250°F. They normally try to operate at 280-290°F inlet temperature to the baghouse located downstream of the spray chamber. This keeps a batter temperature margin above the dew point.

The baghouse is completely insulated. In addition, there are heaters on the collecting hopper and collecting screw conveyor. These electric heaters will be turned on automatically when the temperature drops to below 250°F.

Baghouse maintenance problems in terms of corrosion have been negligable. They do have a relatively high maintenance on the bags. There is a material which tends to crystalize on the bags causing both cracking and plugging. They change the bags completely approximately once per year, which is only approximately ½ of "normal" life.

The acid plant was started up about June, 1972. The entire hot section including all pipes and ducts is completely insulated on the acid plant including essentially everything downstream of the drying tower. The exceptions to this are the cold heat exchanger and blower. It is possible with this arrangement to maintain the acid plant at temperature for periods of from 12-18 hours.

Corrosion has only been noted on the cold portions of the plant where there is no insulation such as on the down corner from the drying towers, the duct to the cold heat exchanger and the acid plant blower. The cold heat exchanger has been retubed once since start-up of the plant.

They have noted deposits of the black organic material which is believed to be the flotation reagent from the ores. They have also noted some sulfate deposits.

They are able to detect when plugging occurs by the incrase in drip acid. This is detected by checking a drain pipe every twenty four hours which is located at the inlet to the blower.

There is an insulated duct from the drying tower to the blower to the cold heat exchanger.

Corrosion has been detected on the main blower. The main blower uses a 1200 horsepower blower and is capable of operating at 150 inches w.c.

He believes that they have collected over a one year period 49% of the input sulfur to the plant. He feels that the number 79% of the SO_2 from the sinter machine is a little high.

The acid plant is bypassed until it is determined by visual inspection of the instrument that sufficient SO_2 is produced to allow acid plant start-up. Once the minimum amount of SO_2 is being generated the acid plant is manually turned on.

C. Telephone conversation with Mr. Ron Johnson, Manager, Lead Smelter, Bunker Hill Smelter, Kellogg, Idaho on May 22, 1974.

Mr. Johnson is the manager of the lead smelter at the Bunker Hill facility. They also have a zinc smelter.

(In a previous conversation with Mr. Gene Baker (the same day) he stated that the sulfuric acid plant on the zinc smelter can be operated continuously and they do not have the same problems as encountered with the acid plant on the lead smelter. The two major problems he cited as occuring with the lead smelter are 1) the continuous starting up of the sinter machine and 2) the black material deposited within the system. On the zinc smelter they do not have a sinter machine and they use flash smelters and are able to operate continuously. Also, the acid produced from the zinc plant is white acid and is not discolored.)

Mr. Johnson was initially quite reticent in answering questions and wanted to know in detail why we were asking for this information. I assured him that we only wanted to obtain experience data on the particular equipment that he had at his plant and were not in anyway concerned with applying regulations to his operation.

He then quite willingly answered all questions put to him.

The Bunker Hill lead smelter takes the gases from the sinter machine and passes them through a water spray chamber where they are cooled to approximately 230°F. The gases then enter the baghouse for particulate removal. After the baghouse they enter a packed tower which is used as a cooling device as well as additional particulate collector. From the cooling tower gases pass into one mist precipitator and then into the acid plant drying tower.

During start-up they build up flow of gases to the acid plant to allow generation of enough heat for autogenous operation. This start-up time might be carried over a period of from 5-20 minutes. It takes, in some cases, as much as 40 hours before the entire acid plant has reached thermal equilibrium.

During the low start-up flow condition channeling of the gases through much of the equipment such as the tank tower and the mist precipitator occurs. This channeling reduces the efficiency of the equipment. In fact, during some start-up the whole plant efficiency may be down as low as 82%. It takes 20-40 hours to get the third pass out of the converter at maximum efficiency.

The sinter machine is on approximately 75% of the time. During start-up, if they introduce toomuch cold gas into the system heat will not be generated at a sufficient rate to reach autogeous operation. This is particularly true if they are down for 15-16 hours. They will bypass the acid plant during the start-up phase.

Mr. Johnson believes that part of the problem at Herculaneum is because of their injecting water into the hood of the sinter machine.

He believes quite strongly that the black "mud" deposited throughout the system is a hydrocarbon material. However, he could not specifically site any tests that had been run on this although he said that they had done so. He seemed quite sure that the back material was not lead or lead sulfates.

He said that it is possible to get material coming all the way through the system as proved one time when they were trying some experimemts with reduced oxygen present over the sinter machine. This caused elemental sulfur to be formed which actually came all the way through and was found in the acid.

They operate at approximately 800°F gases on top of the sinter machine. They try to maintain 235°F gases going into the baghouse. They have not encountered any excessive corrosion in the baghouse.

They have encountered excessive corrosion at the inlet duct to the blower and in the blower itself. They believe that there is still some acid mist coming through at this point.

They have a preheater for the start-up of the converter but it is not too satisfactory because it uses outside atmospheric air. This air contains enough moisture to cause additional corrosion in the system. They have tried to change the system to minimize this acid mist. They have added a knockout tower and in addition a dam and weir set up which seems to be working well.

Mr. Johnson was quite strong in his statement that it was very necessary to have both the baghouse and the mist precipitator operating at peak efficiency. He said that they did get a build up of the "mud" material at the bottom or inlet side of the tubes in the precipitator. It was necessary to keep this clean to obtain efficient precipitator operation.

They change bags in the baghouse at least once a year or somewhat less intervals. He believes that bags made in Europe from acrylic thread appeared to be the best at this time.

Mist corrosion is in the outlet duct from the baghouse to the fan and in the fan housing.

They have been experimenting with a KREBS scrubber which uses a jet of high velocity water impinging on a plate. They have found this, in small scale experimental work, to be very efficient. This design comes from South Africa.

Mr. Johnson said that they were experiencing $75,000 permanent loss because of the operation of their acid plant. He did not think that it would be practical to add either a sulfur burner or liquid SO_2 supply to smooth out and maintain constant operation of the acid plant, because of this fact.

The following data on the Bunker Hill smelter were obtained from EPA Region X.

1. Brief history of SO_2 control at Bunker Hill.

Zinc plant: 1954 wedge roasters converted to flash roaster
Monsanto Plant #1 acid plant installed.

1968 zinc production increased - new flash roaster
Chemico plant #2 acid plant installed.

Pb smelter: 1970 new Lurgi updraft sinter machine and
Monsanto acid plant installed for strong stream.

2. Plant input

- Sources of ore
  - custom smelters: accepts ores of various concentration
  - also uses ores from Bunker Hill mines
  - uses about 30 different types of concentrates per year. (70% local sources)

- Ore sulfur content and variation.
  Pb conc: 65% Pb, 6% zinc, 18% S) Aug. values
  Zn conc: 54% Zn, 1½% Pb, 30% S)
  Small amounts of Cadmium, Hg, Cu, etc.

- Pb plant: Zn oxide, Cu, Silver, Gold, Antimony
  Zn plant: Cd Zinc alloys, Cu,
  both plants: Hg

3. Sinter production

- capacity or prod. rate of sinter machine
  2700 wet tons/day (approx. 2300 dry tons/day
  on time operating factor = 85% annual basis
  approx. 1300 TPD sinter storage
  blast furnace
  1000 TPD return as fines to prep plant
  down time once every 7 days for standard maintenance.

- Capacity of acid plant: Approximately 400 TPD. 32,000 SCFM (1800-32,000)
  min. SO_2 - 5% can get down to 3.5% . Efficiency 97.5% (varies 92% to 97.5%)

- Amount of sinter recycled.
  No sinter recycled, goes back to return prep plant.
  The machine uses gas recycle. Figures not available as to percentage. but #4fan can handle 40,000 ACFM which includes a) combustion air (8000 CFM) b) recycle gas and additional ambient air if necessary i. e., approx. 32,000 ACFM recycle possible.

- Air flow diagram - refer to schematic of sinter machine and flow chart, Figure 13.

- Lead plant (Hi strength) calls for:

  27,900 SCFM dry gas @ 600°F - 700°F
  10,000 SCFM H_2O vapor @ 600°F - 700°F
  5% SO_2 by volume of dry gas
  usual weak stream 30,500 SCFM (dry)
  .9% S by vol dry gas.

  Sample calculation:
  Strong gas from sinter machine 63,800 ACFM (600°F)
  (incl. 8,000 ACFM H_3O vapor)

  At spray chamber gas cooled to 250°F
  (dry gas 37,400 ACFM at 250° F
  H_2O vapor 5,360 ACFM @ 250°F
  Water added at spray chamber = 8,050 ACFM @ 250°F

- Variation of SO_2 across length of sinter machine

Ignition layer	Layer burn thru	Sulfur burn-out complete	
0'	40'	60'	92'

← cooling →

- Air vol and S conc. to main stack
  30,500 SCFM 0.9% by vol. from sinter machine
  goes into main baghouse (no spray chamber)

- Lurgi 1970 updraft sinter machine

- No exceptional sinter machine maintenance problem noted.

- Acid plant reliability very poor - to date has had functional failure with most of the present equipment on stream 50 to 70% of the time.

- B. H. now conducting these experiments - results not in yet.
  - part of State regulation. Recycle low SO_2 thru sinter machine.

Acid disposal	O_2 enrichment
Reduced SO_2 loss	Limestone and scrubbing on tail gas

- No power generation from sinter offgas -
  none for lead smelter - do for zinc smelter

- Quality of acid produced
  - discoloration, high Hg content prior to purification and Hg removal - suitable for use in NH_3 phosphate plant.

- Actual capture of SO_2 limited in past by
  - a) reliability of plant
  - b) markets

- Acid plant tail gas concentration.

  1100 PPM to 4000 PPM
  97.5% Eff. 92% Eff

  Source test data shows

1800 PPM	37000 SCFM
650 PPM	25000 SCFM
660 PPM	

VI. VISIT TO ASARCO EAST HELENA, MONTANA SMELTER FOR PROJECT 046.

A visit was made to the American Smelting and Refining Corporation, ASARCO, in East Helena, Montana on May 13, 1974 to obtain data for the study on SO_2 control for their lead smelter.

Those interviewed were:

Stan Lane, Plant Manager
Bob Hearst, Superintendent
Elden Lindstrom, Assistant Superintendent

A preliminary discussion, with all present, covered the general problems of operating an acid plant with a lead smelter, experience at St. Joe and Amax, the June 21, 1972 summary memo of sinter machine flows and the confirmation and update of this information.

Mr. Lane indicated (as does material given us by Norm Huey) that their studies have shown no local markets for sulfuric acid. He said that this problem is further compounded by the close proximity of large supplies of low cost Canadian sulfur which could be converted to sulfuric acid.

The author was asked and noted that St. Joe experience with their acid plant was marginal but Amax seemed to be able to operate reasonably well. Also, that all of the evidence seems to indicate that most of the problems encountered were the results of not sufficiently modifying the "standard" acid plant design to specifically match the lead smelter needs and operating characteristics.

ASARCO comments on sulfuric acid plant - sulfuric acid market is strongly influenced by the close proximity of Canadian sulfur. Anaconda in Anaconda, Montana makes more sulfuric acid in their plant than they can use. Stan Lane indicated they would not want to get into the fertilizer market because it is a special product requiring an entirely new technology.

They noted that the "new" No. 3 fan (mentioned in the June 21, 1972 memo) did not perform as they had expected and produces only 40,000 CFM instead of 55000 CFM as expected. This caused some additional modification and marginal performance of their recirculation system.

A review of the sinter machine schematic was conducted with Eldon Lindstrom. He said that no further test data had been obtained since the 1972 tests. Additions and corrections to update this material were obtained and are summarized below. An inspection of the sinter machine system completed the interview.

The ASARCO sinter machine was one of the first updraft units installed in this country. It is 100 feet long and 8 feet wide. The updraft section is 72 feet long. It uses a 1½" thick ignition layer and a 14" to 16" final sinter layer.

Normal maintenance on the sinter machine is 8 hours down time per week. This is exclusive of any unforeseen down times. The machine had been shut down for approximately 4 hours for unforeseen maintenance during the day of this visit. Also, the blast furnace had been banked for lack of sinter feed.

Correction of the "old" system schematic shown was made and the "new" system schematic defined in Figure 13. Dust from the cyclone handling gases from several exhaust points is sent back to the sinter machine instead of being collected because of handling difficulties.

From the flow system balance it appears that gases leaving the sinter machine are at a rate of approximately 98,000 SCFM based upon the June 16, 1972 flow data. There has not been any additional tests made since that time and after the plant was modified.

Water spray heads are inserted at 4 foot intervals on both sides of the sinter machine hood just downstream of the main outlet flue. About 18 spray heads located on each side (total 36) supply enough water to cool the outlet gases to 550°F. Each spray head flows 50-70 GPM at 500 PSI feed pressure.

The cooled outlet gases then flow to the main exhaust fan (200,000 ACFM at 500°F). The reason for providing water injection upstream of this fan is to reduce the volume of the gas so as to match the capacity capability of the fan. In addition it is necessary to humidify the gases before they enter the Cottrell precipitator to 50-60% humidity so that the precipitator can operate efficiently.

After the gases pass through the main exhaust fan they enter a rectangular concrete flue which is approximately 300 feet long before entering the precipitator. This precipitator was built in the early 1920s and is an extremely old design. The upper limit of operation was stated to be 175°F because of gas resistivity and the wooden roof. It seems to collect particulate more efficiently below this temperature. At the present time only the precipitator is used for particulate control.

After the gases have passed through the precipitator they are heated again with auxiliary gas heat to raise the temperature well above the dew point before flowing through the stack and out into the atmosphere. The main reason for heating the gases before they enter the stack is to ensure that no acid will be formed which would rapidly erode the cement lined stack.

There is 14-16% sulfur in the new concentrate entering the plant. This quantity of sulfur is reduced to approximately 7% by mixing with recycled sinter and moisture. There is approximately 6-7% moisture in the sinter feed.

Fan operating points are shown in the following table:

Fan	Volume Flowrate ACFM	Gas Temperature $^{\circ}$F	Speed RPM	Static Pressure in W.C.	Power BHP
Main Fan	200,000	500	440	2	116.6
Down Draft	10,000	300	1170	5	13.7
#1	30,000	100	1750	20	108.7
#4	50,000			25	
#2 Westinghouse #40370	33,000	100	1770	15	94.3
#3 (Expected)	55,000	100	1770	10	116.8
#3 (Actual)	40,000 (Approx.)	100		13(Approx.)	

Altitude 4,200 Ft. - East Helena, Montana

Most of these fans are Westinghouse. Where the data are not shown it was not available.

VII. VISIT TO BRUNSWICK MINING AND SMELTING CORP. LTD. NEW BRUNSWICK, CANADA ON JUNE 12 AND 13.

The Brunswick Mining and Smelting Corporation, Limited, Smelting Division, Belledune, New Brunswick, Canada was visited on June 11 and 12 to discuss the operation of their sulfuric acid plant in conjunction with the lead smelter. This smelter uses complete sinter machine gas recirculation, collecting a single stream for direct flow to a single contact sulfuric acid plant. This results in more complete collection of SO_2 emissions than any lead smelter in the United States.

Personnel taking part in the discussions were as follows:

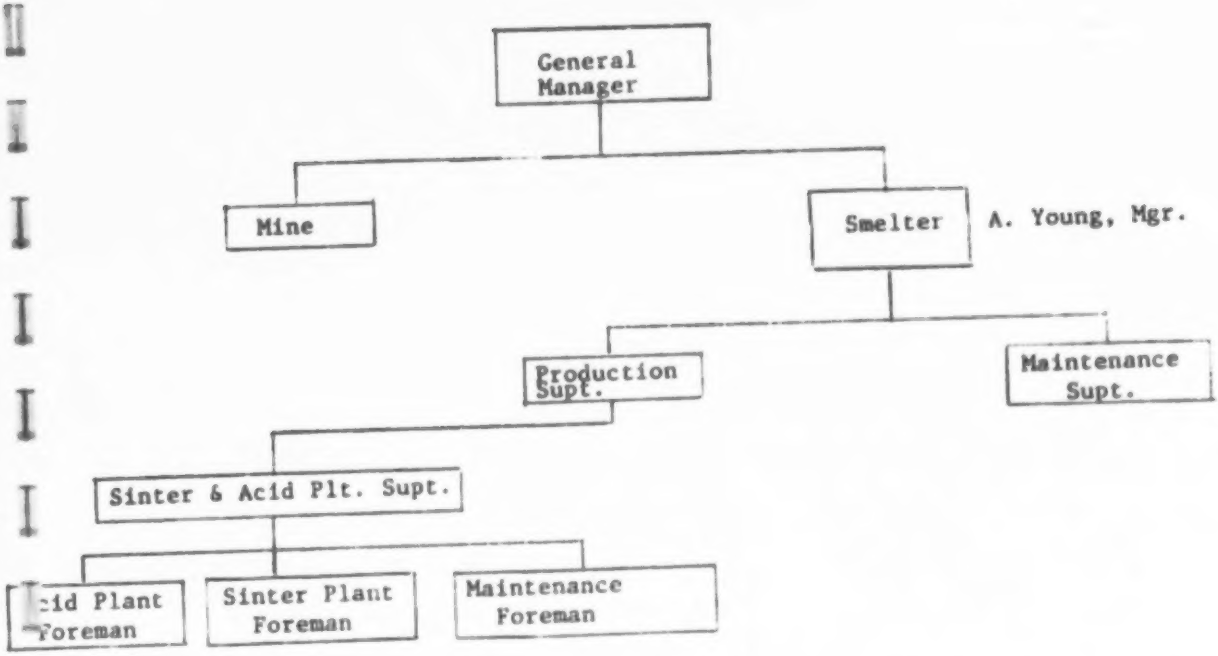
Brunswick Mining and Smelting:

Alan Young, Smelter Manager
Mike Street, Production Superintendent
Peter Dugdale, Technical Services Superintendent (Environmental and Metallurgy)
Bob Nutten, Sinter and Acid Plant General Foreman
Stewart Norton, Sinter Plant General Foreman
Eldon Hickey, Maintenance Coordinator for Sinter and Acid Plants
Bunny Legacy, General Foreman, Acid Plant.
Bud Weisenberg, PES

This is a relatively new smelter having been started up in 1967. It was established to handle ores from a mine located approximately 35 miles away. The entire input to the smelter is received from this mine. The original process in the smelter produced low lead and zinc bullion until about 1970. At this point the cost of coke became so high it was decided to only produce lead and ship zinc concentrate overseas.

The entire operation is presently owned by Noranda Mining & Minerals Corporation. It consists of the mine, the lead smelter (silver, copper, arsenic), the sulfuric acid plant, and a fertilizer plant making super phosphate fertilizer.

The smelter is organized as follows:


General Manager
Mine
Smelter
A. Young, Mgr.
Production Supt.
Maintenance Supt.
Sinter & Acid Plt. Supt.
cid Plant Foreman
Sinter Plant Foreman
Maintenance Foreman

The actual operating crew consists of approximately 15 men per shift with 4 shifts covering a 24 hour 7 day week period. The cleanup crew consists of about 10 men who work only during the day. The entire smelter has a total of 550 personnel. Noranda also maintains a research center at Montreal. They serve as consultants to the smelter.

The concentrate handled is unique to this particular smelter containing 30-40% lead, 30-35% sulfur and 8-10% zinc. This concentrate is lower in lead content and considerably higher in sulfur content than processed by most smelters. The concentrate is produced by a concentrating plant located at the mine site. They use the normal flotation reagents such as the following:

H-31 Starch
Dow Chemical Z-200 -Dithionocarbonate
242 Cyanimide-Dithiophosphate
Amyl Xanthate
Isopropyl Xanthate

The material enters the plant by rail from the concentrating plant. It passes through a thaw shed which in the winter time thaws out the entire rail car for 1-4 days. The new material may be stored in open stock or placed directly in the feed bins.

The feed bins consist of 5 concentrate storage bins of 200-250 tons each, an additional storage bin contains sand (silica) and an additional storage bin containing lime rock.

The feed material loaded on to a belt in proper proportions to obtain a new feed mix consisting of concentrate, lime and silica. The lime to silica ratio is approximately .7.

For every 3 tons of sinter manufactured they produce approximately 2 tons of acid.

The mix is added to recycled sinter material to produce a sinter machine feed containing 6-8% sulfur. This is common to all lead smelters. The sinter machine recirculates the gases generated from the downstream end of the machine and produces a single gas stream which flows to the acid plant. This gas stream normally contains approximately 5% SO_2. A concentration of 6% is preferable for good acid plant operation.

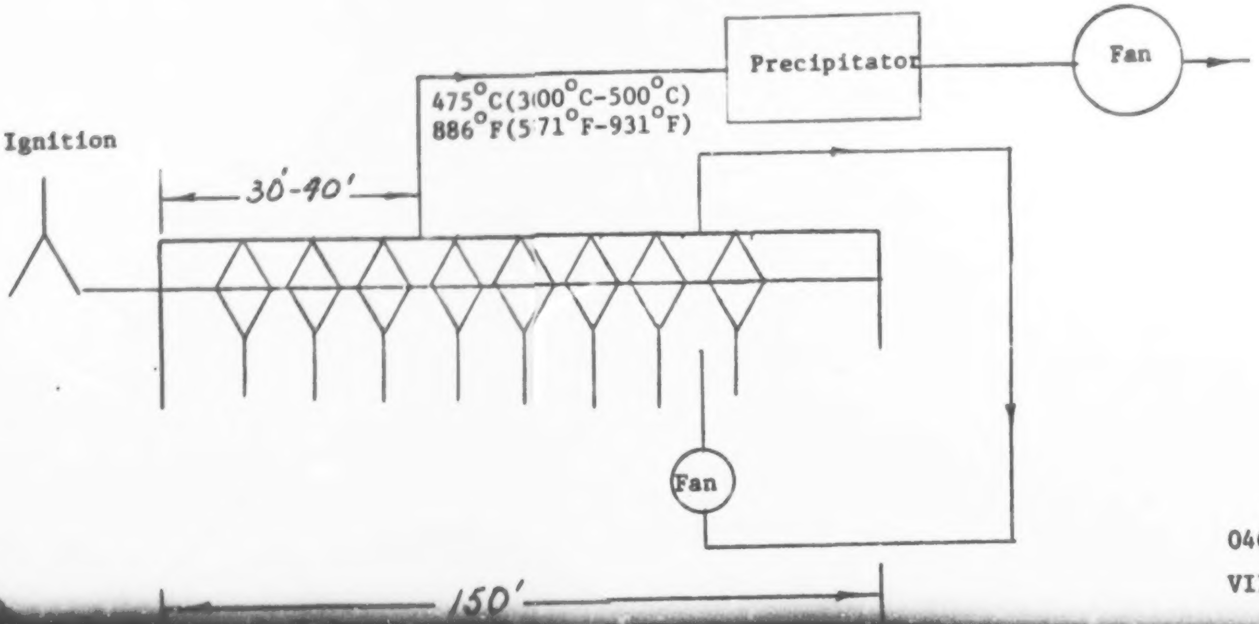
The concentrate containing approximately 30% sulfur is mixed with return sinter containing approximately 2%. Five parts of return sinter are mixed with 1 part of concentrate. Output sinter contains approximately 1.5% sulfur.

The Lurgi sinter machine can handle 1.45 tons of sulfur per 24 hours per square meter. The bed is 120 square meters in area which results in 174 tons per day of sulfur being burned as the rate limit. At 30% sulfur in the concentrate this produces a total maximum input concentrate load of 580 tons per day.

The feed from the feed bins, dust from the precipitator hopper and returns are proportioned and transferred by a series of belts to a mixing drum. Water is added to this drum to maintain a moisture content of 5% by weight, total. The feed is then passed to a balling drum where additional mixing takes place.

The sinter machine is 150 feet long and 10 feet wide with a bed area above the updraft windboxes of 120 square meters. An ignition layer of 1½" is used and is ignited by five oil burners using No. 6 fuel oil. Steam injection with the oil improves the combustion efficiency. Ignition length is approximately 6 feet and ignition time 1½ minutes. The bed travel 4-5 feet per minute. The main layer adds an additional 10-11" thickness of material.

A sketch of the sinter machine system is shown below:



The air supply system consists of one ignition fan and three main fans with 11 windboxes. The following table summarizes the fans and flows:

Fan No.	Windbox No.	Volume Flowrate SCFM	Air Source
Fan No. 1	1-4	18,000 - 21,000	100% Atmosphere
Fan No. 2	5-7	9,000 - 14,000	100% Atmosphere
Fan No. 3	8-11	15,000 - 20,000	Recirculation + some atmosphere
Ignition	Ignition	6,000	100% Atmosphere

A maximum recirculation gas temperature of 300°C is used. If this temperature is exceeded then the volume of the other fans is increased by damper control. The entire air flow is controlled by dampers at each of the windboxes.

The following table shows the gas volume passed to the acid plant with average SO_2 content for various months.

Month	Gas Flow To Acid Plant SCFM	Average SO_2 Percent
January	40,000	4.0
February	48,000	5.5
March	49,000	5.6
April	45,000	5.2

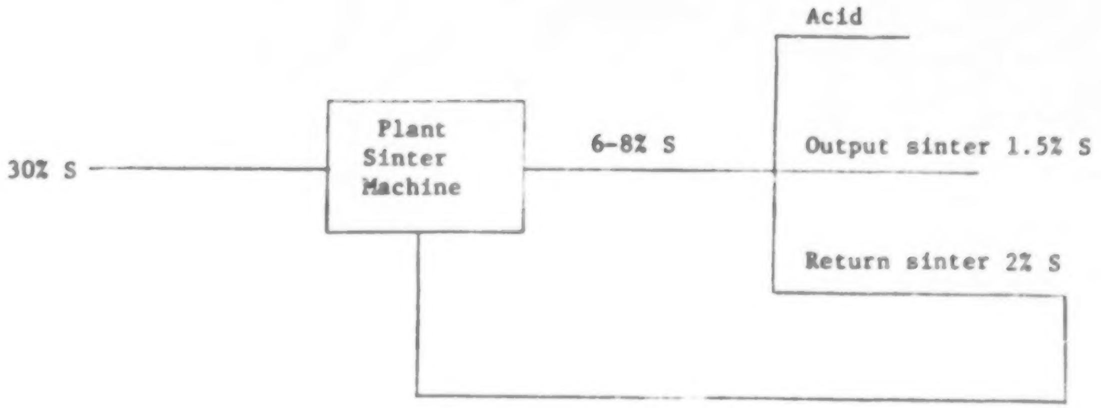
Typical loading history for the Brunswick Smelter is as follows:

Concentrate 67,000 TPY
Lime and sorter mix 17,350 TPY
Total new material 84,350 TPY
Total process weight 422,000 TPY
Recycle sinter 337,650 TPY

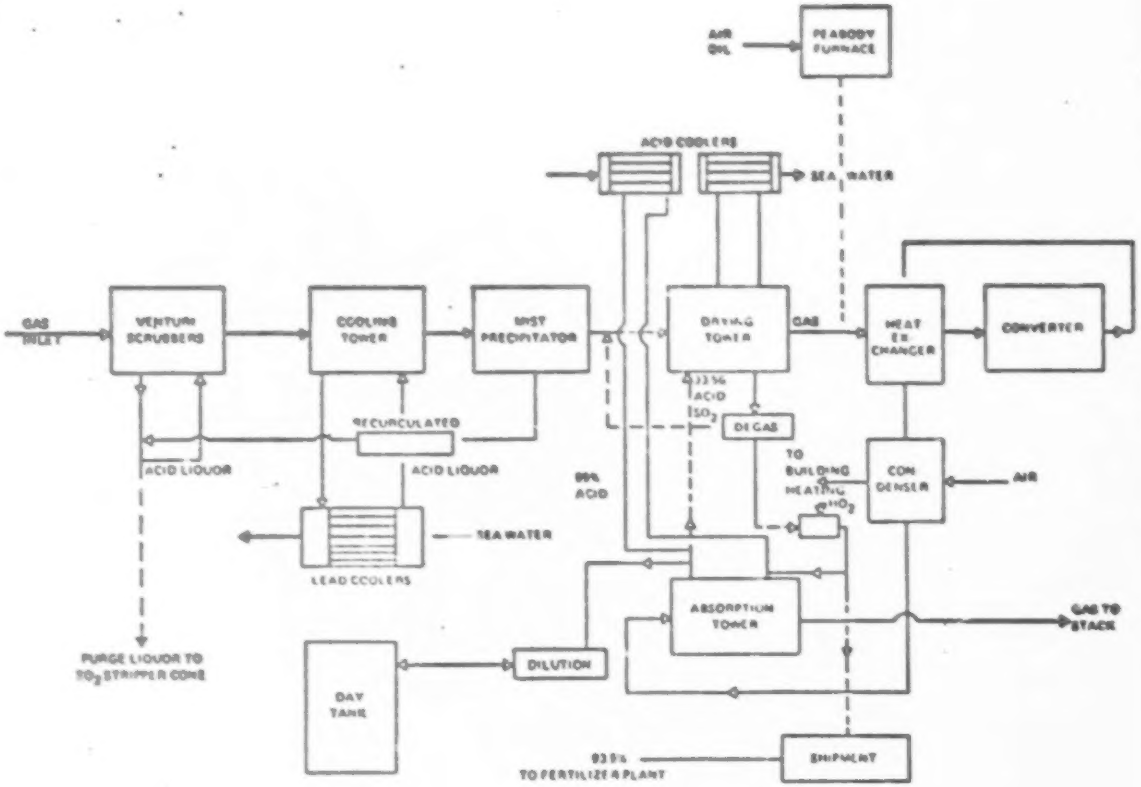
The sinter containing 1.5% sulfur produced is approximately 62,000 TPY. 62% of the sulfur produced goes to slag at 1.75% sulfur. The lead produced contains 0.5% sulfur. 67,000 tons of concentrate produces 50,000 tons of 100% sulfuric acid. The concentrate at 30% sulfur contains 20,100 tons of sulfur and the sulfuric acid at 32.7% sulfur contains 17,310 tons of sulfur. The additional sulfur mixed in the lead and slag will raise the total overall sulfur collection to approximately 90%. Typical monthly production shows the following:

14,300 tons of concentrate producing 4,340 tons of sulfur
11,353 tons of 100% sulfuric acid

The sulfur content is shown in the following sketch:


Acid
Plant Sinter Machine
6-8% S
Output sinter 1.5% S
30% S
Return sinter 2% S

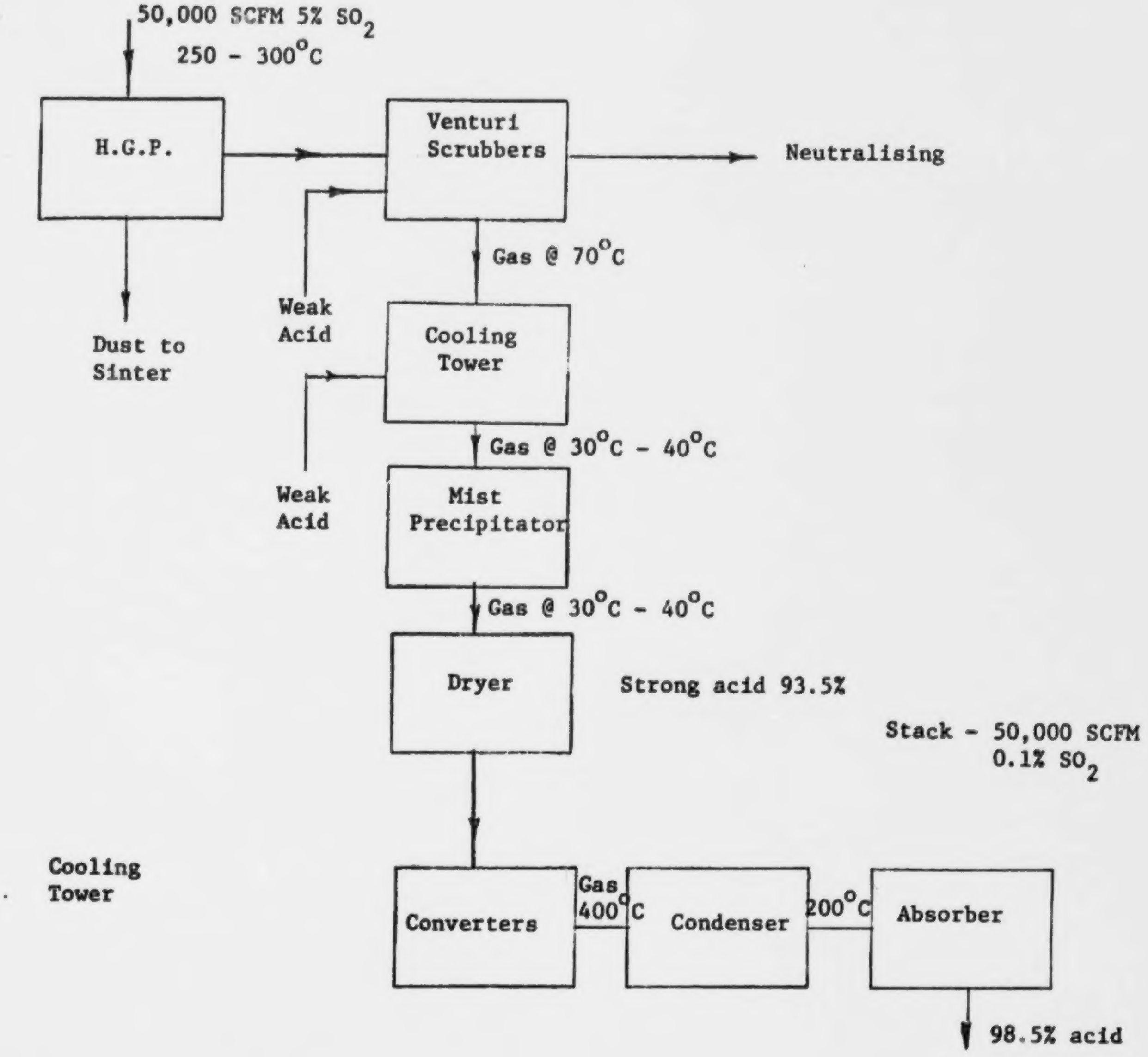
The gases from the sinter machine pass directly to a hot gas precipitator. There is no water or air injection beyond the sinter machine output. From the hot gas precipitator the gases pass to venturi scrubbers and proceed as shown by the following acid plant basic material flow sheet (Page VIII-24)


AIR
OIL
PEABODY FURNACE
ACID COOLERS
SEA WATER
GAS INLET
VENTURI SCRUBBERS
COOLING TOWER
MIST PRECIPITATOR
DRYING TOWER
GAS
HEAT EX CHANGER
CONVERTER
93%
ACID
SO2
DEGAS
RECIRCULATED
ACID LIQUOR
ACID LIQUOR
98% ACID
TO BUILDING HEATING
H2O
CON DENSER
AIR
SEA WATER
LEAD COOLERS
ABSORPTION TOWER
GAS TO STACK
PURGE LIQUOR TO SO2 STRIPPER CONE
DAY TANK
DILUTION
93.5%
TO FERTILIZER PLANT
SHIPMENT

ACID PLANT BASIC MATERIAL FLOW SHEET

The gases leaving the sinter machine are at approximately 300°C (571°F). This is somewhat lower than machines without recirculation and is probably due to the reduction in temperature from the mixing of the cold recirculated gas with hot gases coming off the burning bed. A maximum upper limit of 400°C (751°F) is used as a control point for gases entering the precipitator. At this point an alarm will sound and readjustment of the gas flow will be required. The hot gas precipitator is located close to the sinter machine to facilitate the return of the dust removed to the feed bin for recycle.

The gases pass from the hot gas precipitator to three Venturi Scrubbers. These Venturi Scrubbers use weak acid as the fluid. Since the pressure drop across these scrubbers is very low (1" of water) very little particulate removal is obtained at this point. From the Venturi Scrubbers the gases pass to a cooling tower and into 12 mist precipitators. From the mist precipitators they pass into a conventional Lurgi single absorption acid plant. A sketch showing temperatures at the various points through the acid plant follows:


50,000 SCFM 5% SO_2
250 - 300°C
H.G.P.
Venturi Scrubbers
Neutralising
Gas @ 70°C
Weak Acid
Dust to Sinter
Cooling Tower
Gas @ 30°C - 40°C
Weak Acid
Mist Precipitator
Gas @ 30°C - 40°C
Dryer
Strong acid 93.5%
Stack - 50,000 SCFM 0.1% SO_2
Cooling Tower
Converters
Gas 400°C
Condenser
200°C
Absorber
98.5% acid

Pressure drops throughout the acid plant system are shown in the following table:

Unit	Pressure Drop, " H_2O
Fan Outlet	60
Fan Inlet	14
Venturi	1.0
Cooling Tower	1.5
Mist Precipitator	4
Dryer	6
Fan-Convertor	15
Converter	35

An auxiliary oil fired heating unit is used for start up of the system. This unit will handle 20,000 SCFM which is sufficient to preheat the converter and other parts of the system for startup to autogenous operation.

It is necessary to crush a significant portion of the output sinter to make sufficient material for return.

Sinter machine availability which also takes into account scheduled maintenance down time is as follows:

January	78.5%
February	79.8%
March	80.7%
April	83.8%
May	75.7%

Usually 12 hours per week are established as scheduled sinter machine maintenance down time. They expect to raise the sinter machine availability to 85%.

Sulfur elimination from the sinter machine covered approximately 95% going to the acid and 5% to the sinter. For April 4,130 tons of sulfur eliminated from 14,308 tons of concentrate. For February 3,670 tons of sulfur was eliminated from 11,259 tons of concentrate.

Problems and Solutions

- Sinter machine downtime as has been seen, varies from 10-15%. Startup and shut down of the sinter machine and acid plant do not appear to result in undue problems. The acid plant generally will take from one half hour to one hour for startup after being shut down for a relatively long period of time (8 hours).

The 20,000 SCFM gas heater (Peabody) has encountered problems in cracking of the tube sheet. Cracking resulted from the frequent variation in temperature and the original selection of the wrong material. In some cases when the acid plant has been down for a long time the auxiliary heater will be turned on two hours ahead of sinter machine startup to preheat the converter and the remaining portions of the system.

The acid plant can be operated with a crew of 2 men per shift. One man is in the control room, which is separate from the sinter machine control room, and one man is out in the plant.

The 12 mist precipitators tend to get a build up of solid material at the bottom end of the tube. It is necessary to clean out this build up once a week to maintain sufficient precipitator operation. This is done by taking one off the line each day or less. With continuous maintenance on a regular basis of each of the mist precipitators good operation and no problems are encountered.

There is no "mud" like or oily deposit encountered anywhere in the system. They do see a sludgy greyish yellow deposit that does seem to be encountered in the heat exchanger. However, this deposit can easily be washed out with water. There at no time is a necessity to completely dismantle any heat exchanger. They are usually taken out of the line and water is forced through to clean out any deposits when the pressure drop becomes too high.

There are two cooling towers in the gas input system. These towers are used alternately and when the pressure drop in one reaches to high a value because of partial plugging they switch to the other then clean out or wash down the high pressure drop side.

Very little downtime has been required as a result of problems with the acid plant. For example, in an elapsed time period when the sinter machine was operating for 744 hours a total machine downtime of that time was 180 hours. Only 10 hours of the 180 hours was due to the acid plant problems.

Sea water is used for heat exchanger cooling. They do not have a water balanced problem at this plant except in several months in the summer. They are presently awaiting receipt of an additional plate and frame heat exchanger to add sufficient heat transfer capacity, to eliminate their water balance problem in the summer.

They have had a considerable amount of failure problems recently with their baghouses. Bags have been failing however, total life has been 14 months which is actually somewhat longer than most of the lead smelters in the United States.

VIII. MONSANTO ENVIROCHEM SYSTEMS, INC.

A. VISIT

A visit was made to the Monsanto Envirochem Systems, Inc. in St. Louis Missouri. Those present at the meeting were:

Mr. M.E. Doyle, Sales Manager Process Plants
Mr. Frank Smith, Engineer

A discussion of sulfuric acid plants as applied to lead smelters for SO_2 control was conducted. Mr. Doyle indicated that for a single absorption plant a minimum of 3.0-3.5% SO_2 concentration is required for autogenous operation. For the double absorption plant, a 5% minimum SO_2 stream is required.

The converter requires an 800°F operating temperature which usually occurs with a temperature rise of the inlet of 500°F to the outlet of 800°F. The heat exchanger will use acid or water from 180°F which will rise to 300°F when the gases are cooled to 500°F.

It is necessary to cool the gas in the drying tower to remove water under the following conditions:

100°F removes water with 9% SO_2
80°F removes water with 5% SO_2
60°F removes water with 2% SO_2

No water needs be removed when 76% acid is being made. Monsanto has built a sulfuric acid plant (600 TPD) for a 2% SO_2 stream in Chile. A 600 ton refrigerating unit was used to cool the gases down sufficiently for drying purposes. In addition 2 GPM of fuel was used to heat the catalyst bed continuously for the SO_2 to SO_3 conversion. This plant used 30,000 SCFM gas stream.

Buring sulfur to manufactured sulfur acid considerably simplifies the problem because this not only provides a controllable maximum SO_2 content but also provides heat.

B. TELEPHONE CONVERSATION WITH MR. M.E. DOYLE, SALES MANAGER, PROCESS IN PLANTS, MONSANTO ENVIROCHEM SYSTEMS CORPORATED ON TUESDAY MAY 28, 1974

Mr. Doyle was contacted from Columbus, Ohio.

Mr. Doyle had called PES to answer questions in our letter of May 17, to him regarding sulfuric acid plants.

The following comments relate to this letter.

Additional heating systems could be provided to maintain plant temperatures during a sinter machine shutdown, however, additional capital costs would be required and probably could not be justified. Sulfur burning plants produce 98% acid with SO_2 gas feed cooling down to only 165°F. This means that the gases are saturated at 165°F and naturally contain more moisture than with a sulfuric acid plant used for a lead smelter. Here the gases are cooled down to 100 to 125°F to remove more moisture for making 93% acid.

Monsanto believes that the primary problem causing corrosion is the organics from the lead concentrate that come through this system to the converter. The converter breaks down the organics since it is at about 800°F and causes the organics to burn. Since they are in the presence of oxygen they form CO_2 and water. This water is the primary source of corrosion.

Monsanto uses 93% acid for drying in all wet gas systems.

Bunker Hill has been finding a yellow deposit in their acid plant attached to their zinc smelter. They believe it is a mercury compound.

Spent acid regeneration plants used refrigeration for cooling down the input gases to remove additional moisture. This is done to maintain the water balance. They use steam ejector or mechanical refrigeration.

A 400 ton per day acid plant would probably handle approximately 30,000 to 35,000 SCFM. The volume flow rate primarily determines size and cost of the gas cleaning section. Battery limit capital costs for the conversion section would be approximately 3.9 million dollars for a single contact plant. For a dual contact plant, this price would go up to 4.6 million dollars. A .6 factor can be used for scaling up this capital cost. These costs are exclusive of the gas cleaning system which may be 1.1 to 1.5 times the cost of the conversion section.

Maintenance costs are estimated at approximately 4-1/2% of capital investment.

No guaranteed plant life is given.

They estimate a sulfuric acid plant should last up to fifteen years. Engineering design in time will cover a six to eight month period. It will take six weeks from go-ahead to order platework. Total erection time is expected to be 30 to 36 months at the present time.

The 30-36 months include 22-28 months steel vessels only. This is primarily because of the availability of steel plate. It used to take 12-13 months and now takes 22-28 months for erection of steel vessels.

Four months after erection of steel vessels the plant is ready for startup. Startup usually takes approximately two weeks.

A sulfur burner to provide SO_2 during sinter machine shutdown and also to provide additional heat, is a technically feasible method of minimizing acid plant shutdown. However, the turndown ratio of a sulfur plant is probably 4 to 1. This means that the sulfur burner must be continued in operation at all times or the sulfur will solidify and startup problems on the sulfur burner will be encountered.

Cost of the sulfur burner would add approximately 5% to capital cost, for a 400 ton per day acid plant.

IX. RALPH M. PARSONS COMPANY, LOS ANGELES, CALIFORNIA. DISCUSSION ON SULFURIC ACID PLANTS FOR LEAD SMELTERS

A. VISIT

On April 19, 1974 a visit was made to the Ralph M. Parsons Company in Los Angeles, California to discuss the work they have done in design and installation of single and double absorption sulfuric acid plants. The following Parsons personnel took part in the discussion.

Mr. Tim Browder, Sulfuric Acid Process Manager
Mr. Dick (R.E.) Warner, Assistant Sulfuric Acid Process Manager.

A general discussion of the Parsons Sulfuric Acid Manufacturing System indicated that while they are similar, each plant is uniquely designed to meet its feed and product requirements.

Parsons not only believes that current technology is available to apply an acid plant to a lead smelter but are actually in the initial stages of construction of a single contact plant for Met Mex Penoles, Mexico City, Mexico (Headquarters). This plant is sized for approximately 600 TPD which is only slightly smaller than a unit required for the East Helena Smelter. Rough costs were quoted as follows:

Single contact H_2SO_4 plant . . . . (Exclusive of initial cleaning baghouse)	$5,000,000
This could be capitalized over 10 years at approximately	700,000/year (2,000/day)

With production of 600 TPD

$$\text{Capitalized cost} = \frac{\$2000}{600} = \$3.33 \text{ per ton acid}$$

Operating cost = $7.00 to $8.00 per ton acid

Flourine is present in the gas at the Mexican lead smelter requiring a water spray chamber (tank with spray heads) as an initial gas conditioning step. A scrubber is also used downstream of this unit for further elimination of particulates.

The plant was designed for a 5% to 6% SO_2 stream. It is capable of being expanded to a double contact system with only minor addition and modification. Parsons believes the difference in cost between double and single absorption to be very small - much less than 10%.

Catalytic conversion of SO_2 to SO_3 will be affected if concentration is reduced below 2.5%. Some plants will burn sulfur to compensate during lean periods. Low SO_2 concentration can be used, but plant costs go up rapidly because of additional heat exchangers required to maintain reaction temperature.

Indirect heat must be used to minimize water content. Drying is accomplished to allow 98 + % H_2SO_4 manufacture. If lower acid concentration is required, more water in the treated gas stream can be tolerated.

The Climax smelter in Ft. Madison, Iowa uses an oil fired sinter machine and must handle carbon that comes over. Their exact procedure is not known, but they do form carbon at the initial end of the sinter machine. They have a double contact acid plant.

Parsons recently received an order for sulfuric acid plant for Valley Nitrogen Company in California. They will use the sulfuric acid to make phosphate fertilizer. Most of the phosphate fertilizer manufacturers are located in Florida near the major phosphate deposits in the U.S. It is interesting that a western company should be producing this product which is a superior fertilizer to ammonium sulfate and has a much larger market. Parsons did not know where the phosphate was being mined but did know of some deposits in Wyoming and Montana.

Parsons indicated that they were in the process of installing or upgrading additional sulfuric acid plant capacity of 19,700 TPD; this is mostly new plants. They believe sulfuric acid will be selling for $60 $80 per ton within the next 18 months. One of the major reasons for this is that they believe most existing acid plants will be required to reduce their present thruputs to meet environmental regulations.

B. TELEPHONE DISCUSSION WITH MR. DICK WARNER, RALPH M. PARSONS CO. ON 5/16/74

- He had just talked to Kennecott in Salt Lake City and they can sell all the acid they can make.

- Climax Molybdenum is buying a plant to operate @ 2.7% SO_2 - will use sulfur burner to supply heat and SO_2 - could be automatically controlled.

- He would try to use two sinter machines to even out SO_2 flow - on sulfur burner (2).

- Gas to gas heat exchangers
  Use scrubber to reduce gas temperature as well as remove particulate.

- He said you could go to refrigeration probably add 10% to 15% to cost of plant.

- Could design heat exchangers to be opened by manhole and washed out.
  Could also put in nozzles to wash out.

- For 400 TPD 6% SO_2

Electrical	2000 HP Blower 200 HP Pumps
Water	7000 GPM

Schedule	Month Number
Eng. Design	1-9
Purchase	3-12
Site Prep.	12-16
Construction	16-24
Startup	25

- Cool down after precipitator and then reduce temperature to condense out moisture before entering drying tower minimum $\Delta T = 2\text{-}3^\circ F$.

X. TELEPHONE CONVERSATION WITH MR. BOB BERGER CHEMICO, NEW YORK, N.Y. ON JUNE 6, 1974

(212) 239-5856

Scheduling for fabrication and installation of an acid plant is as follows:

Operation	Month
Process Engineering	3
Equipment Engineering	5
Foundation Design	5-9
Structural	4-7
Buildings and Services	7-8
Piping Engineering (Drafting)	4-11
Electrical	4-11
Instrumentation	3-13
Specs. and Standards	10-11
Construction	11-26
Startup	5

There contracts generally call for five consecutive days of satisfactory operation and production as an acceptance requirement.

Mr. Berger could not answer the other questions we asked.